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EDITORIAL

IN this issue we reprint in full an address delivered by Dr. H. E. Shortt, F.R.S., Director of the Department of Parasitology of the London School of Hygiene and Tropical Medicine, as part of the Festival of Britain programme in June, 1951. We believe that Dr. Shortt's lecture should be brought to the notice of everyone working for the betterment of conditions in tropical countries—whether in medicine, agriculture or some other field.

It is very easy for the Agricultural Officer or specialised research worker to become so immersed in his never-ending daily tasks and problems that he loses sight of broader issues. Dr. Shortt takes one particular subject, the diseases of man and his domesticated animals caused by certain protozoa. Whilst describing their effects on man and beast in some detail and outlining methods of control, he still emphasises the overall impact of these diseases on human economy and stresses the necessity of taking into consideration all factors in the ecological *status quo* before applying drastic control measures. He cites particularly the dangers of soil erosion attendant upon overstocking brought about by the control of protozoal diseases of cattle. There are many unfortunate instances where this broad outlook has been obscured by immediate benefits. The dust bowls of North America and the rapid erosion

of hill slopes which have been deforested and brought into cultivation are obvious examples.

Dr. Shortt takes three diseases to illustrate his theme ; the direct effects of two of them, trypanosomiasis and East Coast fever, on agricultural industry in the tropics are obvious and enormous. The effect of the third, malaria, is no less enormous, but perhaps less obvious. The loss of productive effort, without a corresponding lowering of food consumption, caused by malaria is incalculable.

This leads us to consider the relative merits of medical and agricultural science as means of improving conditions of life in the less developed areas of the world. From the immediate humanitarian point of view, the benefits to be derived from developing medical services are obvious ; but it is frequently argued that unless medical progress is accompanied, or better, preceded by agricultural progress, the results from a world economics point of view will be disastrous. This may be partly true in overpopulated areas; but in less densely peopled countries, and even to some extent in overcrowded ones, the greater productive effort made possible by the eradication of debilitating but often non-fatal diseases may well counterbalance the increased food requirements. Agricultural progress is still essential for the maximum development of improved conditions, but cannot be expected to reap its full benefits without the aid of medical progress. The point we wish to make is that agricultural and medical progress in under-developed countries are essentially complementary ; neither must precede the other ; neither can be fully effective without the other.

We publish an article by R. Gane on page 150 on the refrigerated gas storage of bananas. Important as it is to improve the yield and the quality of crops, it is equally important to see that they are delivered to their markets in the best possible condition and with the minimum of wastage. Agricultural Officers are frequently called upon to handle the storage, shipment and marketing of tropical crops and products, and often their training can do little to equip them for these responsibilities ; the only training may be actual—and often hard—experience. We hope to be able to publish more articles in the future on the after-treatment of tropical crops and crop products.

REVIEW ARTICLES AND BOOK REVIEWS

GENERAL AGRICULTURE

THE EFFECT OF FERTILIZER APPLICATIONS ON THE YIELDS AND NODULATION OF TROPICAL KUDZU (*PUERARIA PHASEOLOIDES*)

Tropical Kudzu is a valuable legume throughout the Colonies but not much is known about its response to lime and fertilizers. In the Proceedings of the Soil Science Society of America for 1952 appears a short but interesting article on this point by G. Samuels and P. Landrau. The authors describe a pot experiment on a Puerto Rico clay of pH 4.4 where calcium carbonate at an estimated rate of 5 tons/acre gave large increases in yield and greatly increased nodulation. Sulphate of ammonia (half ton/acre) gave an even greater yield increase but suppressed nodulation. Calcium carbonate plus ammonium sulphate gave the greatest increase in yield and nodulation was suppressed to the same level as for ammonium sulphate alone. Borax at 30 lb./acre with calcium carbonate gave a yield of the same order as ammonium sulphate alone with the greatest suppression of nodulation.—G. ap G.

THE USEFUL AND ORNAMENTAL PLANTS OF TRINIDAD AND TOBAGO

By

R. O. Williams and R. O. Williams Jr.

Guardian Commercial Printery, Port-of-Spain 1951. *Revised Fourth Edition, pp.* 335. *Price* $2.00 (*B.W.I.*).

This book is the fourth edition of a work first published in 1927 which has proved, over the years, to be of immense value to agriculturists, gardeners and botanists throughout the tropics. It consists essentially of the terse descriptive comments, common names and uses of the economic plants grown in Trinidad and Tobago whether they are natived, naturalised or cultivated, useful, ornamental, noxious or merely interesting; there are useful keys to aid identification. Much new information has been added in the process of preparation of this edition and the result, once more, places us deeply in the authors' debt. The book is well made and printed.—N.W.S.

Materia Vegetabiles

Acta culturae et praeparationis plantarum. Dr. W. Junk, *Holland. Editors*—C. Regel *and* F. Tobler. *Price* 40 *Dutch Guilders per annum for* 4 *parts, each of about* 100 *pages.*

This new journal is the organ of the International Commission for Plant Raw Materials and is explicitly " dedicated to the whole domain of vegetable raw materials. It will be a connecting link on the one hand between research, cultivation and extraction, amelioration, preparation and utilisation on the other."

The first number of this journal (Vol. I, 1, 1952) covers, as might be expected from the foregoing, a wide field : South African grazing problems, the culture and improvement of flax and linseed in South America, technique of resin production in Austrian forests, the Caesalpinias as tanning materials, experiments with Yucca, the significance of terpene accumulation in plants, the utilisation of the fibre of edible bananas and the distribution and uses of Styrax in Greece. These eight papers are written in French, English and German and with two exceptions, have summaries in another language. This is in accord with editorial policy that papers shall be written in the language of the author, with a summary in a second language (though the two exceptions noted above represent an early departure from that policy). There are also a number of reviews.

To the reviewer, the quality and cogency of the contributions seem unequal and some might surely have been sharply cut down in bulk. Furthermore, the field covered seems to be much too wide ; no one worker is likely to be interested in more than a very small minority of the papers. Journals "which one ought to see in case there is something one should read " are simply a nuisance. It is to be hoped that editorial policy in future will be changed so as to restrict the field covered, to insist on conciseness in the papers accepted, and to ensure the presence of a satisfactory summary in a second language.

Printing and production are quite good.

N.W.S.

A WORLD DICTIONARY OF BREEDS, TYPES AND VARIETIES OF LIVESTOCK

Commonwealth Bureau of Animal Breeding and Genetics Technical Communication No. 8. Edinburgh. Pp. viii+272. *Price* 30 *shillings.*

THIS dictionary, the newest member of that excellent family of publications emanating from the Commonwealth Bureau of Animal Breeding and Genetics in Edinburgh fills another gap on the reference bookshelf. This work will prove invaluable to livestock breeders and animal geneticists, and is a necessary purchase for the library of any agricultural faculty.

The first edition, as the author points out, contains omissions and errors as is to be expected in any original edition of a reference work. However, the book represents a monument of endeavour and the author is to be congratulated upon another bold step forward in the fight for a uniform international nomenclature, on this occasion in the realm of farm livestock.

The format of part one is excellent especially the use of heavy type to denote only the recognised breeds. Part two clearly demonstrates the great lack of vital livestock statistics over a very large area of the globe.

It is to be hoped that the author will be given the utmost co-operation by animal breeders the world over in his efforts to compile a companion series of breed photographs and distribution maps.

The writer would also like to see the scope of the dictionary extended so as to include other livestock species, e.g., The Camel, the domestic fowl, Ducks, Geese, Turkey, Pheasant, &c.—J.R.H.

THE DAIRY FARMERS' VETERINARY BOOK

By Norman Barron, M.R.C.V.S., Ph.D. (*4th Edition*) *Dairy Farmer* (*Books*) *Ltd., Ipswich,* 1952. *Pp.* 188. *Ill. Price* 15*s.* 0*d.*

Dr. Norman Barron, a veterinarian of repute, is also gifted with the rare ability of being able to translate technical jargon into simple English. His Dairy Farmers' Veterinary Book has been lucidly written, not for the Veterinary Surgeon, but for the stockman who requires to know when to send for the ' Vet ' and what to do meanwhile.

In 2 years this book has run into 4 editions, evidence enough of the excellence of both the contents and format. The book contains several well chosen photographic illustrations, and many well drawn and labelled diagrams.

The chapter dealing with Sterility and Infertility demonstrates the great change in attitude that has occurred in recent years with regard to this subject. Previously the subject of Fertility and Sterility was jealously guarded as the province of the Veterinary Surgeon. The enlightened dairyman of today to compete economically, must know a great deal about the anatomy and physiology of reproduction and milk let down. These aspects are briefly discussed and the subject of pregnancy diagnosis in dairy cattle is clearly explained in simple terms and diagrammatically illustrated.

Certain chapters are not applicable to the tropics but the greater part of the book deals with the princip'es of animal health, hygiene and first aid and these are the same whether one milks Jerseys, Goats or Water Buffalo. This volume should therefore be most useful to all Advisory Agricultural Officers and Dairymen throughout the tropics for both reading and reference purposes.

J.R.H.

JAHRESBERICHT DES FORSCHUNGSINSTITUTS FUR KAKAOWIRSCHAFT e.V., *Hamburg*, 1951, *Pp.* 32, *Ill.*

THE Cacao Research Institute, Hamburg, was founded in 1951, under the presidency of H. Otto Bertram and the direction of Dr. Oskar Kaden, a well-known name in the field of cocoa research. The first Annual Report of the Institute is presented in an attractive illustrated booklet of 32 pages.

In addition to introductory matter and details of the affairs of the Institute, the report contains fourteen papers of a technical nature, of which nine are reprints of papers delivered at the inauguration ceremony on 16th August 1951, and three more have since been reprinted in *Gordian*. The papers are mainly of the review type, as would be expected from the short time the Institute has been in existence, and cover a wide range of topics, including pest problems, the composition and examination of fermented cacao and other matters of interest to cacao importers. A new patented process for treating underfermented and diseased cacao is described, which is claimed to convert ordinary cacaos into " new types of cacao, equal in flavour and aroma to fine cacaos ". This post-fermentation has been christened *Okadieren* (presumably translated as *Okadise*, *Okadising*, *&c.*), and one awaits with interest the reaction of the chocolate industry to the new process. Another paper deals with the classification of cacao beans by the anthocyanin content, determined photo-electrically; the work of Hallas (1949) on the same subject could have been consulted with advantage. The work on the detection of " stinkers " in cacao beans by means of high-frequency measurements shows an interesting and refreshing tendency towards novel techniques.

The *Jahresbericht des Forschungsinstituts fur Kakaowirtschaft e. V.* is a welcome addition to the literature of cacao research, and the new establishment is to be congratulated on its flying start.—K.W. De W.

Reference: Hallas (1949): "The Anthocyanin and Tannin Content of Cocoa " *Res. Rep.* **13**, B.F.M.I.R.A., Lond.

LATERITE AND LATERITIC SOILS

By

J. A. Prescott, c.b.e., f.r.s. and R. L. Pendleton

Commonwealth Bureau of Soil Science Technical Communication No. 47, *pp.* 51. *Price* 6 *shillings.*

At last the Agricultural Bureaux have broken away from the dull format to which they had become apparently indissolubly attached and it is a pleasure to record that the first of the attractive new booklets to reach the hands of this reviewer is on this fascinating subject and by these eminently well qualified authors. The Australian school of pedologists on the one hand and Professor Pendleton on the other have in the past decade methodically set about laying the " laterite " ghost which has been the bogey of students for half a century. Their success in doing this is of profound philosophical significance to pedology, representing as it does a triumph of objective study against that curse of soil science, enthroned authority.

This is an excellent publication, well illustrated and with a full bibliography, which will be a best seller among the literature of pedology. The reviewer may be pardoned for regretting the reference to termites in the discussion of vesicular laterite. This suggestion, unsupported by any but the slightest observations, can, it is thought, be regarded as a contribution only to the mythology of the subject.—G. ap G.

THE CHECK-LIST OF BIRDS OF THE WEST INDIES

By James Bond. *Academy of Natural Sciences of Philadelphia. 3rd Edition,* 1950. *Pp.* 200.

Man's encroachment on virgin forest and swampland, indiscriminate shooting, and the introduction of rats and mongoose, have been factors contributing to the extinction of approximately fourteen species of West Indian birds in the past hundred years. Numerous other rare or local species may possibly be headed for extinction.

The author has sought to indicate the status of all birds known to inhabit or to occur in the West Indies, and he believes that the present edition of the check list gives a nearly accurate picture of the bird life of the islands at the present time. The status of the various " winter residents ", and the time when the transients may be expected on the islands, is indicated by the inclusion of the earliest known dates of arrival and latest dates of departure of North American migrants.

This check list, which has been prepared with the earnest hope that many of the rarer forms may yet be saved from extinction, virtually completes the systematic study of West Indian birds, although much field work remains for the student.—M.H.B.

THE IMPACT OF PROTOZOA ON WORLD ECONOMIC PROBLEMS*

By

H. E. SHORTT, C.I.E., M.D., D.Sc., D.T.M. & H., F.R.S.
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Reproduced, with permission, from the British Medical Journal, No. 4740, *November* 10, 1951.

In the short time at my disposal it will obviously be impossible for me to do more than skate around the fringes of my subject, but I hope to produce enough evidence about some of the more important protozoa affecting the economy of mankind to indicate beyond any cavil or question that the subject of my address deserves immediate, energetic, and well-directed action.

The phylum Protozoa is a large one both in number of species and in distribution on the earth and in the water, and its members exercise an influence in these spheres which, while immense and essential, is still merely one part of the integrated ecology participated in by animals, plants, and inanimate nature. The part played by protozoa in this ecological complex is too vast a field to be more than mentioned, and so I propose to concern myself only with some of the parasitic protozoa which, by their direct action, affect the social economy of man. As examples of these I shall confine myself to three groups of protozoa which I have chosen as examples partly because of the great importance they possess for man, but also because they are groups upon which man can exert a direct influence to lessen their impact on his economy. The three groups I have chosen are the trypanosomes, the plasmodia, and the piroplasms.

The Trypanosomes

By this term I do not wish to imply the whole family Trypanosomidae, but merely the genus *Trypanosoma*. The trypanosomes have been recognized as of importance to the economy of man since the discovery of Evans in 1880 of a trypanosome which caused "surra," a disease of horses, camels, and other animals. In 1902 Forde was the first to recognize trypanosomes as a cause of disease in man in Africa, and the knowledge which has since accumulated of their ubiquity in and importance to the domestic animals of man, especially in the African continent, has made them one of the major problems requiring attention if meat and dairy products, which constitute so important a part of man's dietetic needs, are to be made available in quantities adequate for the continually growing population of the world.

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* Lecture in connexion with the Festival programme organised jointly by the British Medical Association and the Royal Society of Medicine, delivered on June 26, 1951.

I propose here to do no more than mention the ravages produced by trypanosomes in man on the east and west coasts of Africa and in South America, important as the effects of these were and are on the distribution, vitality, and general welfare of the populations affected. This is because, from the broader aspects of man's economy, I consider the trypanosomes affecting man's domestic animals to be far and away the more important when the whole picture is looked at in perspective. As Hornby (1949) has stated, trypanosomiasis has the unique distinction of being the only disease which *by itself* has denied vast areas of land in Africa to all domestic animals except poultry. These areas total one-fourth of the land surface of the continent. Apart from these completely unstocked areas, there is a still greater aggregate of land surface in every continent except Australia where trypanosomiasis is one of the major scourges of stock. The factors concerned and the results brought about by trypanosomiasis can be illustrated by Vogt's formula $C = B : E$, where C is the carrying capacity of the land, B is the biotic potential, and E is the environmental resistance. In this study I wish to indicate how much C is lowered by the part of E due to trypanosomiasis.

Still limited by my time allowance, I can consider only bovines among man's domestic animals, but, as these are among the most important of animals used by him as food, the effect of infections on them will serve as a measure of the full effect of trypanosomes in reducing the quantity and quality of beef supplies and dairy products.

Three Main Groups

The most important trypanosomes pathogenic to bovines fall into three main groups, which, in the absence of easily applied differentiating specific characters, I shall refer to as the *vivax* group, the *congolense* group, and the *brucei* group. In some areas one is the prevalent pest, in others another, while very often two or even all three may coexist and take their toll of stock. The members of all these groups are carried from animal to animal by various species of tsetse fly, so that the protozoological problem now becomes linked with an entomological one. While cyclical transmission by tsetses is the normal method, it would be unwise to assume that direct mechanical transmission by other biting flies is of little importance. The proof of this is the establishment of foci of *Trypanosoma vivax* endemicity in South and Central America, Mauritius, and the West Indies, where tsetses do not now occur.

The distinction between these three groups is relatively simple from the entomological angle, as the dissection of infected flies will supply the answer in any given area. When tsetses display the presence of cyclical forms in the salivary glands we can say the infecting trypanosome belongs to the *brucei* group. When the infection is found both in the midgut and in the mouth parts, the cyclical forms being in the latter situation, the trypanosome belongs to the *congolense* group, while the presence of multiplying trypanosomes in the mouth parts alone indicates the *vivax* group.

It would be fruitless to make any estimate of the bovine population of even one continent such as Africa, and much less of the world. Of all the continents, however, it is in Africa that trypanosomiasis ranks most highly as a cause of cattle losses, and it would be interesting, therefore, to know the degree of risk to which cattle are exposed in, or passing through, fly belts in Africa. Mere impressions are often unreliable, and the amount of accurate evidence on this point is limited, but certain detailed observations recently made by Unsworth (1951) are revealing.

Mortality and Morbidity Due to Trypanosomiasis

In the course of experiments devised for other purposes, 10 control cattle were introduced into an area infested with *Glossina palpalis*. All contracted infection with trypanosomes and all died within 146 days. The trypanosome concerned was *T. vivax*.

In similar experiments in another area 10 control cattle were introduced into an area infested with *Glossina morsitans*. All became infected with trypanosomes, eight died within 81 days, one died after 154 days, and one escaped after 110 days but was later found dead—probably owing to trypanosomiasis. The trypanosome concerned was again *T. vivax*. Admittedly these figures are small, but they relate to carefully controlled experiments and are an indication of the losses which would be sustained by unprotected cattle in areas infested by either *G. palpalis* or *G. morsitans*.

These experiments, while striking evidence of the potentially disastrous consequences of bringing cattle into such areas, need not be regarded as necessarily applicable everywhere. There is good evidence to show that there are considerable strain variations in virulence, so that *T. vivax* in one area may produce a virulent infection with high mortality, while in another area the infection may be mild with low mortality.

Mortality, however, is not the only criterion of the damage sustained by herds due to trypanosomiasis. Affected cattle, even if they do not die, often lose condition to a marked degree, are emaciated and weak, and such animals, if trekked to markets or otherwise subjected to strain of any kind, will often succumb when they might have survived if rested. But rest is not the fate of most cattle in Africa. The cattle of the Fulani, those nomadic herdsmen, have to follow their food, and, as the seasons of the year change and grazing grounds alter, must accommodate their movements accordingly. These wanderings sooner or later bring them through fly belts, and the consequences, in the absence of protective measures, are inevitable. The only possible way to prevent this wandering habit, which, after all, is dictated by the need for water, would be the provision of permanent water supplies, but, as this is a matter for engineers and is outside the scope of my paper, we need not pursue the subject further, although it will come in for brief mention at a later stage.

Mortality and loss of condition, however, are only part of the failure to reach maximum productiveness in numbers and economic usefulness of bovine resources. These are direct losses in existing herds, but quite immeasurable are the indirect losses due to the exclusion, on account of the presence of trypanosomes and tsetses, of what would be vast potential herds from pastures otherwise admirably suited for them. Still more indirectly one has to consider the losses due to overstocking in fly-free areas on account of the restriction of grazing grounds due to the presence of tsetses. Such losses include also the effects of loss of condition, helminthic and bacterial diseases, and infertility.

All this means that the mere mortality in herds due to trypanosomes in any particular area is only a very partial picture of the losses, actual and potential.

Control Measures

This brings us, logically, to consider control measures. These, although outside my present subject, must be touched upon, as they are the natural concern of all who are faced with the practical control of trypanosomiasis. They resolve themselves into measures, direct and indirect, against the tsetse and direct measures against the trypanosome, or a combination of these.

Direct measures against the tsetse are confined to the use of insecticides. Such means may be of value against species such as *G. palpalis* with a limited range or a range limited by environmental factors, such as belts along river courses, but are at present inapplicable or would be inordinately expensive against species such as *G. morsitans*, widely dispersed over large areas. In any case, the indiscriminate use of insecticides on such a large scale might have unexpected and harmful effects due to unselective slaughter of insects.

Indirect measures have probably a wider and more useful application. These consist of selective clearance of bush under skilled supervision in the case of riverine tsetse, and settlement and agriculture of fly-infested areas, where this is possible, in the case of the more widely dispersed species, such as *G. morsitans*.

I do not propose to go into the subject of bush clearance, which is a highly specialized affair, but would merely draw attention to my use of the word "selective" in regard to bush clearance. Preservation and improvement of water supplies is of paramount importance in Africa, and therefore indiscriminate removal of blocks of forest or of fringes of forest along river courses is indefensible if it can be avoided. Possibly, chemical means of destruction of tsetses along the edges of sharply cut corridors in the forest would suffice, the corridor giving access to the river for watering.

G. morsitans is essentially a "game" fly, and goes when game goes. In this way agricultural development and settlement alone will remove it. As

food, it prefers game to cattle and cattle to man, but it must be remembered that mere clearance of game without alteration of the other conditions suitable for *G. morsitans* might merely substitute cattle as a perfect alternative to game. On the other hand, agricultural development means an increase in the human population, with consequent and essential changes in the fly's environment, until an increase in the population up to 200 or over per square mile will so alter conditions as to eliminate *G. morsitans*.

We have here been considering only the control of tsetses, but it must not be forgotten that mechanical transmission of trypanosomes by biting flies may be an important method of transmission. *Trypanosoma evansi* is transmitted wholly by this means, although there is a distinct possibility that it may once have been cyclically transmitted by tsetses but have lost this capacity, while *T. vivax* has spread far beyond tsetse areas and maintained itself by mechanical transmission, still retaining its transmissibility by tsetses. Thus, as already mentioned, it is now firmly established in South America and other tsetse-free areas.

Prophylaxis

Direct measures against the trypanosome are treatment of infected animals and prophylactic treatment of cattle. There are drugs now available, and more seem to be on the way, which are effective in the treatment of trypanosomiasis in cattle. The efficacy, however, is not equally potent against all species of the trypanosome. One of the latest of these drugs is phenanthridine 1553, which has given striking results from treatment by a single subcutaneous injection of 1.5 mg. per kg. body weight of a 1 per cent. solution. Cases of photosensitization following this treatment have been remarkably few. Successful as this treatment has proved, such drugs may be of still greater value when used prophylactically on herds which have to pass through fly belts or have to live in fly-infested areas. Such use would not only prevent infection of the cattle but would protect the cattle of uninfected areas from infection by imported infected cattle.

The value of " antrycide " used as a prophylactic has been investigated in a series of carefully controlled experiments by Unsworth (1951), whose conclusions were:

> " It would appear that the effectiveness of antrycide prophylactic mixture in protecting cattle against infection and death from trypanosomiasis depends very largely on the intensity of the trypanosome challenge to which the cattle are exposed. Where the quantum of infection is low, such as might result from exposure to riverine tsetse in Northern Nigeria, the inoculation of cattle at three-monthly intervals with antrycide prophylactic mixture will give complete protection against death and will protect 88 per cent. to 95 per cent. of cattle against infection with trypanosomiasis. The small proportion of cattle in which trypanosomes do 'break through' the drug are apparently cured by subsequent inoculations. Where, on the other hand, the quantum of infection is great, such as might result from exposure to an average challenge from *G. morsitans*, the inoculation of cattle at three-monthly intervals with antrycide prophylactic mixture cannot be relied upon to give complete protection, either against infection or against death from trypanosomiasis. Moreover, such a procedure is not unattended by danger, for in the experiment which we have just described at Lumu there were indications of the development of an antrycide-resistant strain of trypanosome, eight months after the cattle had first been introduced to the area."

His conclusions indicate the uses and limitations of antrycide as a prophylactic, and may be taken to summarize the present position as regards prophylaxis.

A Controversial Question

Having now considered the effects of trypanosomes on human economy we have to deal with the more controversial question of what might happen were we able by one means or another altogether to eliminate the pathogenic cattle trypanosomes.

I must refer again to Vogt's formula C = B : E. C, representing the carrying capacity of an area, would not necessarily be augmented by eliminating trypanosomiasis. Even if we leave out of consideration other bovine diseases, protozoal or otherwise, there remains man's cupidity, which might result in his attempting to keep a larger stock of animals than the land at his disposal could with advantage support. It may be, therefore, that trypanosomiasis acts as one of the checks on this evil, and that careful thought should be taken before removing it entirely in any care-free manner.

We have to bear in mind the fact that although tsetses limit the areas where stock can thrive or even exist, yet they are not a bar to their existence to the extent that many people imagine. On the contrary, there are great areas where large numbers of domestic animals succeed in existing in contact with tsetses so long as the latter are not numerous or effective enough to cause repeated infections.

In areas from which the presence of tsetses utterly debars stock, though otherwise suitable for them, the removal or reduction in numbers of tsetses would allow the land to be made use of and so greatly increase the carrying capacity of the country and lead to a better distribution of stock. This would also tend to prevent overstocking of areas at present usable and overstocked. Tsetses, however, are not the only factor influencing distribution of stock; there is, as I have already said, the distribution of permanent water, which in its turn influences the distribution of human population, with consequent effects on agriculture and the diminution in numbers of tsetses which follows this sequence. There is a third factor governing distribution of stock which we consider in another place—namely, tick-borne disease ; and yet a fourth, helminthic disease, which, however, is outside the scope of this paper.

Were we to remove, if it were possible, all these factors limiting the increase of stock, the numbers of the latter would certainly lead to overstocking and greatly accelerated soil erosion, so that there would result an economic evil which would be largely irreversible. This same overstocking would also result in an increase in the incidence of many other diseases of stock—viral, bacterial, protozoal, and helminthic—so that better distribution would be of all-round benefit. However, the complete removal of limiting factors is not in sight, and I only sound a warning. On the other hand, there is no doubt that tsetses do cause overstocking of areas free or relatively free from flies and

so hasten soil erosion in them. The removal, therefore, of tsetses or of trypanosomes would allow a better distribution of stock and so act indirectly as a measure of soil conservation. It would also help in more widespread use of composting to fertilize the hungry soil.

To sum up, the menace of trypanosomiasis is bound up with many other menaces, and all these should be considered as an intimate complex in devising and putting into effect measures of limitation or prevention. Only in this way can we ensure that man's economy in regard to more and better supplies of meat, milk, dairy products, and agricultural crops shall be best served and debilitating deficiency diseases be reduced.

The Plasmodia

In the previous section it will have been seen that the impact of protozoa on man's economy was primarily on his food supplies, and thus only indirectly on man himself. In the case of the plasmodia the direct impact is on man and only indirectly on his food supplies and general economy. The impact in this case has a much wider contact than in the case of the trypanosomes, for there is no continent where plasmodia do not exert a major influence on man's activities, even to the extent, in some tropical areas, of prohibiting them entirely.

Now when one considers the relatively low mortality from malaria over the entire population, even in areas of high endemicity, one might imagine at first that the effect on man's general economy would be small, whereas we know that, in truth, the effect is enormous. This apparent paradox is due to the fact that the influence of malaria is exerted for the most part indirectly. While relatively few die, enormous numbers are debilitated to a greater or lesser degree, work hours are lost, physical capacity for work is lowered, mental capacity is impaired, and the vigour and vitality of a people are diminished. All these damaging results are roughly proportional to the degree of endemicity, and I am in disagreement with those who assert that a very high degree of endemicity has little effect on the economy of the people affected. The argument of this school of thought appears to be that in such an area there is a high degree of immunity, or rather tolerance, in the adult population and the adult is looked upon as the main or chief economic unit. This seems to me to be a very one-sided way of looking upon the picture.

In a community such as that envisaged, the high adult tolerance is accompanied by a high infant mortality, and in assessing the effect on the general economy of the community in a long-term view this wastage must be taken into account. Among figures given by Wilson (1936) for a tribe living in Tanganyika in an area such as we are considering, the average number of children surviving to women who had completed their child-bearing life was only 1.13. If we take the sex ratio as approximately 1 : 1, this means that only one woman in two would have a surviving female child to produce children of her own. It is only too evident that such a community would be a dying one unless reinforced by immigration.

It seems to me quite irrational to maintain that such a community has a healthy economy because its adult population shows a tolerance to malaria enabling the adult unit to work more or less continuously and with a minimum of lost working hours. It may be true that the working units are in a stable condition of health as regards malaria, but the community as a whole is like a man living on his capital and having no regularly paid income to keep him in a financially sound condition.

In order to get some idea of the total effects of the plasmodia on man's economy one has to consider this economy as a many-sided figure and to examine each facet separately.

In pre-human days, when man was a higher ape wandering in the forests in smaller or larger family groups, it is possible that he lived, as some of the primates now appear to do, in a partnership with his malaria parasites. Each group would occupy a relatively limited tract of country, and the aggregate of all these groups would be infinitely small as compared with present human populations. Each group, which might be composed of several families, would be infected with its own strain of malaria parasite, and in the course of time would develop an immunity or at least tolerance to that strain on evolutionary lines by the continued survival of the more resistant individuals. A time would arrive when the pre-human being and his malaria parasites would have come to a *modus vivendi* whereby mammal would provide a habitat to protozoan, and protozoan would cause a minimum of inconvenience to mammal.

The pre-human being, however, having a divine discontent with his limited surroundings, began to wander outside his group's natural terrain and so came in contact with other groups. In this way adjacent groups might amalgamate into larger communities, which probably accelerated the human evolutionary process and led towards much greater agglomerations of fully human communities. This led inevitably to man coming into contact with strains of plasmodia foreign to his old economy and against which he had little or no immunity. In other words, part of the price man paid for progress towards true manhood was an increasing tribute to malaria.

We may now consider the forms which this tribute took and the effect it had on man's economy.

Effects on Distribution of Population

When one examines the distribution of people on maps of the world it becomes evident that the most important single factor encouraging or limiting this distribution is the presence or absence of permanent surface fresh water, in the forms of rivers or lakes.

It does not follow from this that areas with the most lavish water supplies are necessarily the most thickly populated, because other factors besides

water are in operation. This would apply, for instance, in the great Amazon basin, with its mighty rivers and forests but very sparse human population. On the other hand, scarcity of water is always accompanied by a sparse population, as in the desert or semi-desert areas. That this sparsity is due to lack of surface water is exemplified by the relatively small population in most of Iraq and the country between Mosul and the lower Tigris and Euphrates, where formerly a much denser population with thriving cities, such as Ur, Babylon, Nineveh, and others, once existed owing to a vast irrigation system of communicating canals. When these fell into disrepair owing to various causes, the ravages of the Mongols among others, the cities and the thriving population were swallowed up in the arid desert. It would appear, therefore, that on a world scale malaria does not play a decisive part in the distribution of population.

Plenitude of water, however, facilitates occupation by both mosquito and man, the latter on account of its use for his agricultural activities. According to Macdonald (1950), in some such rich agricultural areas in Africa *Anopheles gambiae* has been unable to prevent a concentration of population, although in India and Ceylon there are large areas where, in the absence of preventive measures, *A. fluviatilis*, *A. minimus*, or *A. culicifacies* deny the use of the land for human settlement. Thus in certain foothill areas of the Himalayas and of the Western Ghats of India the country is almost uninhabited owing to the presence of the almost exclusively anthropophilic *A. fluviatilis*.

Effects of Redistribution of Population

We have so far been considering the effect of malaria on more or less static populations, but we must now look into what happens when population movements on a greater or lesser scale take place. The causes of such displacements are varied. Migration of population may be due to the pressure of overpopulation in healthy and prosperous areas, causing a spill over into more malarious country. It may be due to mass movement of labour to areas where public works such as dams or bridges are being constructed, or of labour required in mining and similar large-scale operations. There is a third form of two-way migration in certain parts of India, where a population normally engaged in agriculture flocks in large numbers to cities, such as Bombay, to work in cotton mills during the off season in agriculture and returns to the latter occupation for the sowing and harvesting seasons.

In all these cases, except possibly the last, the tendency is for the population to move from a less malarious to a more malarious area, but this is not invariably the case. The effects, however, in the absence of preventive measures are the same—an increase of malaria sometimes on a disastrous scale, either on the immigrants or on the population of the area invaded. Although many other factors come into operation in producing malaria in epidemic form under the conditions cited, the most important factor is probably one inherent in the malaria parasite itself.

It is well known, and can easily be experimentally demonstrated, that the immunity to malaria parasites is species-specific. This means that a mammal infected with one species of malaria parasite cannot be super-infected with the same species, but may easily be infected with any other species to which it is susceptible. In other words, a man carrying *P. vivax* cannot be super-infected with *P. vivax* but can easily be infected with *P. falciparum* or *P. malariae*. This specific premunition goes even more deeply than species, because it is found to be not merely species-specific but also strain-specific. Thus a man carrying a strain of *P. vivax* acquired in area A cannot be super-infected with that strain, but can be superinfected with a strain of *P. vivax* derived from area B. These facts supply the clue to the danger of introducing populations from non-malarious to malarious areas or even of introducing populations well adapted to one species or strain of parasite to an area where a different species or strain is present.

Where no precautions are taken such movements of population may have disastrous results. To cite a case coming within my own experience, I may mention what happened in one area of Assam during the recent world war. In the mainly rice-growing district of Sylhet the country is very low-lying, a mere 20 feet or so above mean sea level, although situated 150 miles from the sea. The communications are by earth roads raised above the level of the surrounding country. The villages are mostly situated on the highest ground available. During the monsoon the whole country is inundated and the villages exist as island areas connected by the raised roads. In spite of these conditions the district was relatively non-malarious and the population non-immune. Large numbers of the men had gone to work as labourers on military works situated in malarious districts. When these returned to the area in question many were infected with strains of malaria parasites from the districts in which they had been working. The result was disastrous. A suitable carrier species of anopheles already existed ; out of a population of about 40,000 people in this particular area some 7,000 to 8,000 died of malaria before any effective action was taken.

This is an instance of an infected population moving into an area of very low endemicity, but the results may be equally unfortunate when a comparatively healthy population enters an area of high endemicity or, as already stated, even when a so-called " salted " population moves into an area where their immunity to their own strain of malaria is comparatively inoperative against the new strains or against a different species of parasite. In other words, almost any kind of redistribution of population in malarious areas, even when the endemicity is not high, is likely to be accompanied by severe epidemics of malaria.

The possible economic effects of such disastrous epidemics will be only too obvious. The life of the community is completely dislocated, and this may be accompanied by a state of apathy that prevents any energetic action by the community itself, which can be saved only by outside help.

This is a very comprehensive aspect, and includes effects on agriculture, industry, social services, including education, and the general welfare of the population.

Looked upon from this angle, the effect of malaria on a community may mean anything from a slight inconvenience to an almost complete cessation of individual and community activities. In the milder degrees of malarial endemicity the chief effect will be in the form of days lost to all beneficial activities on account of illness among the workers. This effect may be much greater than would be expected from the number of days lost, especially in tropical communities where, as Macdonald (1950) has pointed out, the success or otherwise of agricultural operations very often depends on the climatic conditions obtaining during a limited part of the year, generally that part when ploughing and sowing are carried out. If the sickness among the population coincides with this period the days lost and the impaired physical condition of the workers will have an effect on their productive capacity the results of which will endure throughout the remainder of the year in a way which would not have been the case had the malaria been prevalent at a less important part of the annual work cycle.

The effect will be further enhanced by the fact that children as well as adults are sure to be affected, and in most primitive communities the older children are themselves economic units in the community.

This represents the effect on the economy of a community working for itself, but under the same conditions the effect is the same when such a community is employed as labour in some local industry. The absenteeism and the diminished physical capacity, added to wastage of labour, needing new recruitment, and to provision of special measures of housing and medical care, will inevitably lead to loss of time in completion of projects and to a greatly added cost. There is no aspect of the life of the community which escapes the impact of malaria even in the milder forms we are considering. The future economic units, the children, are frequently ill, leading to absenteeism, which interferes with education and may in many produce a constantly recurring invalidism, conditions under which the child will certainly not receive the full benefits of attendance at school, and the money and other resources applied to an educational policy will not bring commensurate results until the harmful influence of malaria is eliminated.

To proceed from a consideration of the conditions we have been contemplating where malaria merely slows down the pulse of a community, let us see what happens when malaria in severe epidemic form lays a community prostrate.

Only if such a catastrophe has been personally seen can any conception be formed of the extent of the blow struck upon the community. Such

epidemics usually occur in areas where malaria transmission is chiefly confined to certain periods of the year and seldom, if ever, in hyperendemic areas where transmission is going on throughout the year. Typical of such epidemics was what has happened in the Punjab on various occasions, in Ceylon, and in various other parts of the world.

During one of the Punjab epidemics a village in the affected area at the height of the epidemic presented an astonishing sight *and sound*. The following account was given me by an eye-witness:

> Most of the dispensaries of the district were closed because the staff were ill, and those open were neglected for the same reason. The countryside looked empty ; cattle were wandering about unattended. As one approached a village a curious moaning sound was heard. This was the lowing of cattle waiting in vain to be milked. More than half the population were lying on " charpoys " unable to get up and neglected by all. Others were sitting about unable to work. Many huts had collapsed in the rain and remained unrepaired. Everyone looked half-starved, because none were well enough to grind the corn or fetch water for making "chappatis." Many young children and the old died of starvation, the former because their mothers could not attend to them. Many dead were lying untended on "charpoys" or on the ground. The village had ceased to exist as a human community. All the destruction was not directly due to malaria. Malaria was the *fons et origo mali*, but in its train starvation and dysentery played their part. Family ties were loosed, and brother did not care for brother or mother for child.

In case some of you should think this picture exaggerated, let me say that I have myself seen conditions where corpses were left unattended not only on the roads and by the wayside but even, in more populated places, on railway platforms. In other words, the whole organized structure of a community disintegrates on the failure of its human elements.

The general account I have given will leave no one in doubt about the profound effect of malaria on a community. The full effect may sometimes not be evident from a mere perusal of statistics showing the number of malaria cases occurring in a district and of mortality from malaria. A very striking instance of this was brought to my notice by Professor Macdonald. In Ceylon the total mortality over a period of nearly 50 years remained at a high relatively uniform level. In late 1946 effective antimalarial measures were begun, and in the next three years there was a very notable decrease in the *total* mortality. As the only notable new public health measure taken during this period was malaria control, the improvement can only be attributed to this, and is an indication of the direct, if not always apparent, effect which malaria exerts over the economy of a district, an effect which is much greater than would be expected from the known mortality due to malaria itself.

Sinton (1935) has calculated that in India alone 1,000,000 deaths a year are caused directly by malaria, another 1,000,000 are caused indirectly, and the number of cases of malaria occurring annually is 100,000,000. These figures seem incredible from one country alone, but on my putting this question to Professor Macdonald he said that, although at one time he was disposed to discredit the figures, his own subsequent studies have led him to the opinion that they may be an underestimate.

The Piroplasms

The two types of protozoal parasites I have already dealt with, showing how severe is their impact on man's economy, are probably more familiar to most of you than the one I am now going to deal with—namely, a piroplasm, using this term in a broad sense. This is because both the former attack man as well as animal and so force themselves more directly upon our notice. The piroplasms, on the other hand, so far as we know, are animal parasites only, but their impact upon the animal food supplies of man makes them at least as important as the trypanosomes and plasmodia.

In the sub-order Piroplasmedia there are two families, the Babesiidae and the Theileriidae.

The piroplasms are parasites of a very large range of mammals—cattle, sheep, goat, pigs, horses, dogs, monkeys, antelopes, rodents, and other groups, so that their impact on mammals is a wide one. But, strangely enough, man seems to be immune, and the effect on his economy is entirely due to losses caused by this group to his domestic animals. I have already indicated the wide range of animals affected, but, again limited by my time allowance, I shall take as an example one group alone—the bovines. Cattle are parasitized by members of both the families I have mentioned, Babesiidae and Theileriidae, and each is the cause of various diseases of cattle, such as redwater, East Coast fever, and other diseases due to miscellaneous "small piroplasms". By far the most important of these diseases of bovines is East Coast fever, caused by the piroplasm *Theileria parva*, and I shall deal mainly with this in order to give a somewhat fuller account of its importance than could be attempted were I to deal with the other piroplasms as well.

East Coast Fever

In order to give an intelligible account of the effects of East Coast fever, I must describe, in the shortest manner possible, the life history of the causative parasite, as on a knowledge of this will depend methods of combating its menace to the food supplies of man.

East Coast fever is a blood-and-tissue infection of bovines with the parasites above mentioned, and is transmitted by various ticks such as *Rhipicephalus appendiculatus* and other species. The parasite in the blood is a minute organism 1-2μ in diameter which attacks the red blood cells. Inoculation of blood into susceptible animals does not reproduce the disease, so presumably the blood forms are gametocytes destined for sexual reproduction in the vector tick. Asexual multiplication takes place in endothelial cells of the internal organs and glands, where intracellular masses of blue cytoplasm studded with minute red granules represent schizonts which are known as Koch's blue bodies. These break up into very numerous minute merozoites which re-enter other endothelial cells or parasitize the circulating blood as the before-mentioned gametocytes.

When infected blood is taken up by the vector tick, whether adult, nymph, or larva, development of the parasite takes place, with the production of sporozoites. Now, each of these stages of the tick is passed on a separate

host, and the parasites taken up by one stage are transmitted to another host by the next succeeding stage of the tick. The adult tick, when infected, does not transmit the infection through eggs to the next generation of larvae, as happens in the case of various species of *Babesia* such as the one responsible for red-water fever.

This is the explanation of some of the anomalies found when the two infections are compared. Thus every egg laid by a redwater-infected female tick produces, when hatched out, a larva which can at once infect another animal. On the other hand, eggs deposited by ticks infected with East Coast fever produce uninfected larvae, which have to feed on an infected animal before they become infected. After their first feed they drop off the animal and attain the nymphal stage, in which they, in their turn, are infective. The adult female dies after laying eggs. In this way a very few cattle infected with East Coast fever can provide infection for many thousands of larval ticks, which in the nymphal stage are infective. The symptoms of East Coast fever begin 10–20 days after exposure to infection and start with fever. Lymphatic glands become enlarged and there is oedema of the subcutaneous tissues, intestinal mucosa, and serous membranes, with haemorrhagic patches. Calves are less susceptible than adults. The fever continues until death or recovery.

East Coast fever has existed, certainly for centuries, in East Africa, and was well known to the natives before it forced itself on our attention. It is most prevalent in well-grassed areas with high rainfall, and absent or sporadic in arid districts. It is widely distributed on the eastern side of Africa, but appears to be absent on the western side.

Mortality Due to East Coast Fever

It is difficult to get reliable figures on this point, and, in any case, it would seem probable that mortality varies in different districts and in different classes of cattle—European and indigenous. This will be evident from the opinions given by different observers: (1) East Coast fever is the cause of more deaths in cattle than all other causes put together ; (2) the calf mortality from East Coast fever varies between 5 and 50 per cent. ; (3) in South Africa the mortality from the natural disease is 95 per cent. ; (4) deaths in bovines, the property of Europeans alone, in Kenya for 12 months ending July 31, 1928, were 16,728 out of 55,421 deaths from all other causes.

All this goes to show that, whatever the actual mortality rate, East Coast fever, where it exists, is far and away the greatest parasitic killing disease among bovines.

Another way to assess the relative importance of East Coast fever is supplied by the records of laboratory examinations for diagnosis of cattle diseases. I have examined the records available to me of laboratory examinations made in Kenya, over a period of 26 years, for the diagnosis of disease-producing organisms in bovines. These I have recorded in tabular form, but it will serve the present purpose if I indicate totals only. These are as follows :

Proportion of Diagnoses of East Coast Fever to all Other Diagnoses in Bovines

Year	Total Positive Bovine Specimens Due to Disease-producing Organisms Sent for Examination	No. Positive to East Coast Fever or Other Piroplasms, or Suspicious
1909–10 ...	413	344
1910–11 ...	939	847
1911–12 ...	900	699
1915–16 ...	1,101	505
1916–17 ...	813	395
1917–18 ...	550	357
1919–20 ...	829	671
1921 ...	1,321	938
1922 ...	1,340	475
1923 ...	1,153	456
1924 ...	1,407	769
1925 ...	2,586	1,594
1926 ...	4,808	1,969
1927 ...	2,670	1,929
1928 ...	2,072	1,640
1929 ...	1,445	1,008
1933 ...	1,581	865
1934 ...	1,426	774
1935 ...	3,037	434
1936 ...	3,286	741
1937 ...	1,564	696
1938 ...	1,877	947
1948 ...	557	284
	37,675	19,337

This assessment would give the astonishing result that diseases due to piroplasms, chiefly East Coast fever, are responsible for 51.3 per cent. of all diagnoses of disease-producing organisms. Now, even this gives no real idea of the economic importance of East Coast fever. The figures mentioned are merely those of specimens sent for examination. It takes no account of the probably immensely greater number of cattle affected but from which no specimens were sent, and it takes no account of the fact that these figures are for Kenya only. The figures have also to be considered in conjunction with the actual numbers of cattle in the area before an idea can be gained of the economic impact of this disease. I am indebted to Dr. E. Beaumont, Director, Veterinary Services in Kenya, for an estimate of the cattle population of Kenya, based partly on actual census-taking and partly on estimates. This indicates a cattle population of 5,773,554. To add to the blackness of the picture, mortality is not the only cause of economic loss, because infected animals which do not die are often badly out of condition and may remain stunted for a long time. This account might make you wonder how cattle exist at all on the east side of Africa. The fact is, of course, that areas of prevalence of East Coast fever are not continuous, nor are they all seriously equally affected.

Control

Methods of control do not strictly come within the scope of my address, but must be touched upon in general terms ; and I do not propose to say anything at all about treatment of the disease.

Control measures are naturally directed against the ticks which are the vectors of the disease, and it is important to know that these measures can be very effective when properly applied and maintained. To put it in a few words, these methods are dipping, hand dressing, and fencing. These measures, carried out under strict supervision, are economically sound on valuable dairying land and can reduce the tick population over very large farms to proportions that are no longer a menace to the herds.

Conclusion

Man in his own estimation is the most important and culminating result of evolution in nature. How far this may be from the truth past events in the evolution of living things, which for a time dominated the earth and passed away, have shown. As for the future, we cannot see it, so it behoves us to take a humble view, especially in the light of the most recent achievements of *Homo sapiens*. From our immediate point of view, however, we must consider man as just one unit in the vast complex of nature and realize that too great success may be disastrous. If he eliminates all the pests and diseases which afflict him he may multiply and eat up the earth and so destroy himself as the result of his success.

For these reasons, I would like to sound a note of warning against the danger that pests such as I have described should be treated, when preventive measures are considered, as if they produced their harmful results without reference to accompanying factors in their natural surroundings. Control measures must be devised in relation not only to destruction of a specific pest but in relation to all other circumstances which might follow the elimination of a single important unit in an ecological complex. Thus if the object in some areas is the complete removal of trypanosomiasis or piroplasmosis we must first consider whether this would not involve the production of a still more serious problem of soil erosion. Preventive or eradicative measures in such a case would have to be carefully planned in collaboration with experts on land usage *before* being put into operation, or we might find ourselves in the position of regretting the results of successful eradication when irreparable damage to the land had supervened.

In other words, an all-round approach must be made, and only after careful preparatory research should important measures of control be undertaken.

It must be remembered that in the case of bovines, which alone I have been able to consider, the chief evil at present is overstocking, and this is due to limitation of grazing lands by parasites of one sort or another. The scientific way of approaching the problem when eradication of pests is undertaken would be, in the first place, to use the method to reduce overstocking in areas already free of the particular pest or pests, and only then to try to increase the total head of cattle by extending still further the use of pasturage made safe by the eradication measures.

The theme, therefore, on which I would wish to close my address is a quotation from the report by H. E. Hornby on *Animal Trypanosomiasis in East Africa*, 1949, because I am sure that he would agree that his words have a wider significance than the context in which they were used. The quotation is : "The point to be driven home is that animal husbandry demands both pasture management and disease control. Improvement of pastures often encourages parasites by giving these protection from the sun, therefore, it must be accompanied by disease control. This alone leads to overstocking so it must be accompanied by pasture management to save the soil."

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COMMUNICATIONS ON ORIGINAL INVESTIGATIONS

PILOT PLANT EXPERIMENTS ON THE REFRIGERATED GAS-STORAGE OF GROS MICHEL BANANAS

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Introduction

Of the bananas imported into the United Kingdom since the war, approximately half have been Jamaican. (Table I).

TABLE I

Imports of Bananas 1946–50*
(long tons)

Source		1946	1947	1948	1949	1950 Jan.-Oct.
Jamaica	Gros Michel ...	49,681	61,766	67,223	69,675	52,079
	Lacatan ...	—	29	342	1,584	5,108
Other	... ...	50,243	42,814	81,678	84,881	53,528
Total	... ...	99,924	104,609	149,243	156,140	110,715

*Figures supplied by the Ministry of Food.

Most of the fruit from Jamaica has been of the Gros Michel variety which is susceptible to attack by *Fusarium cubense*, the fungus causing " Panama Disease ". The Lacatan variety which is immune to this disease has been used to re-plant areas infected by Panama Disease and since 1947, when the Lacatan came into commercial production, the quantity exported has steadily increased.

For transport from the West Indies to this country Gros Michel bananas are cut at the " $\frac{3}{4}$ full " stage and stored thereafter as quickly as possible in the holds of the vessels carrying the fruit at a temperature of 53–54°F. which is the lowest temperature at which the fruit can be stored and subsequently ripened satisfactorily. Lacatan should be carried at a slightly higher temperature (not less than 58°F.).

The " $\frac{3}{4}$ full " stage of ripeness is reached eighty to ninety days from the time the flower bud emerges from the pseudo-stem when the individual fingers have reached their full length, but are angular in shape with five prominent ridges and flat sides. At this " $\frac{3}{4}$ full " stage the fruit will not normally commence to ripen at 53°F. within 14 days. If left on the plant, the fruit swells until the sides become curved and the ridges less distinct. It is then " *high* $\frac{3}{4}$ *full* " or " *heavy* $\frac{3}{4}$ *full* " and its storage life before commencing to ripen at 53°F. is reduced to about seven days. After this the fruits become well rounded and are " *round-full* " and may be expected to commence ripening in two to three days at 53°F.

As the fruit develops the pulp increases in weight at a greater rate than the peel. Thus, in the experiments in Jamaica, summarised below, the increase in weight of the pulp and peel are shown in Table II.

TABLE II

Size Grade	*Average weight per finger (grams)* *pulp*	*peel*	*ratio*
$\frac{3}{4}$ full	63	54	1.17
High $\frac{3}{4}$ full	82	63	1.30

The flavour of the ripened fruit is considered to improve as the size increases.

The grade of banana required for a particular market is determined by the shipping time. Thus the relatively short voyage to the North American market (about 7 days) allows the shipment of " heavy $\frac{3}{4}$ full " bananas but the longer voyage to the U.K. necessitates cutting at the " $\frac{3}{4}$ full stage ".*

It is impossible, however, to ensure that all the fruit in a cargo is of exactly the same grade, and it therefore happens in any cargo that the heavier grade fruit may have started to ripen towards the end of the voyage. Fruit which has started to ripen is known to cause other fruit to begin to ripen through the influence of the traces of ethylene which ripening fruit produces. It is probably for this reason that, in the carriage of banana cargoes, considerable emphasis is put upon the need for ventilation with fresh air.

The shipment of bananas from the West Indies has also been complicated by the effects of the " Leaf Spot " disease. Both the Gros Michel and the Lacatan varieties are susceptible to " Leaf Spot ", an invasion of the foliage by *Cercospora sp.* This disease is now wide-spread in Jamaica. Severe infection with *Cercospora,* which causes defoliation of the plant and the production of stems of fruit of abnormal shape and with diminutive fingers, is rarely encountered in exported fruit but milder degrees of infection which

* There is only one certain way of observing the commencement of ripening and that is by following the rate of carbon dioxide-production, noting the point at which this begins to rise.

are not easy to detect in the fruit, cause premature ripening. The data obtained by Wardlaw and his collaborators (1) show that fruit obtained from plantations which have been affected with *Cercospora* is characterized by pulp of a more or less marked buff colour ; it tends to ripen prematurely, to chill during the period of refrigerated transport, and to ripen with undesirable rapidity on removal to a higher temperature. Moreover, the bunches produced by infected plants tends to remain of small size, hence fruit may actually be considerably more mature than is indicated by its appearance, and departure from the normal storage behaviour for that grade may be expected.

The ripening which occurs at the temperature of the holds (53–54°F.) does not result in fruit of good quality. In order to get good quality, ripening must be initiated after the cargo has been landed and must take place at temperatures of about 68°F. The ripening of the green banana in Great Britain is initiated in warm rooms and the temperature of the banana after that should not be allowed to fall.

The results of experiments carried out by Wardlaw at the Low Temperature Research Station in Trinidad, and published in 1940 (2), suggested that the application of refrigerated gas storage to the transport of Gros Michel bananas from the West Indies to Great Britain would provide a greater margin of safety in avoiding the commencement of ripening during the voyage and enable rather heavier (fuller) grades of fruit to be shipped than had hitherto been possible with refrigeration alone.

The Trinidad Experiments

The Trinidad experiments (Wardlaw (2)) were carried out on a laboratory scale. The single hand, not the bunch, was generally used as the experimental unit. The control of atmospheric composition on this small scale was carried out either by continual ventilation of the small containers with prepared gas mixtures or by restricted ventilation. The first of these methods would be expected to remove ethylene produced by fruit which had begun to ripen, but the second would not. "Heavy or high $\frac{3}{4}$ full" fruit was held in gas storage at 53°F. for 20 days without commencing to ripen, and when thereafter the fruit was transferred to 68°F. it ripened normally. Comparable fruit held for the same period in air storage at 53°F. began to ripen in store and when thereafter it was transferred to 68°F., the quality of the fully ripened fruit was poor both as regards flavour and consistency. If fingers showing incipient ripening were included in the gas storage trials, the results were not satisfactory, and this was attributed to the initiation and progress of ripening in the artificial atmosphere at the low temperature (53°F.).

The Jamaican Experiments

After the war the study of the refrigerated gas-storage of bananas was resumed. Facilities were provided in Jamaica by the Colonial Office for pilot plant experiments on a scale of 20–25 bunches (about 800 lb.) per unit.

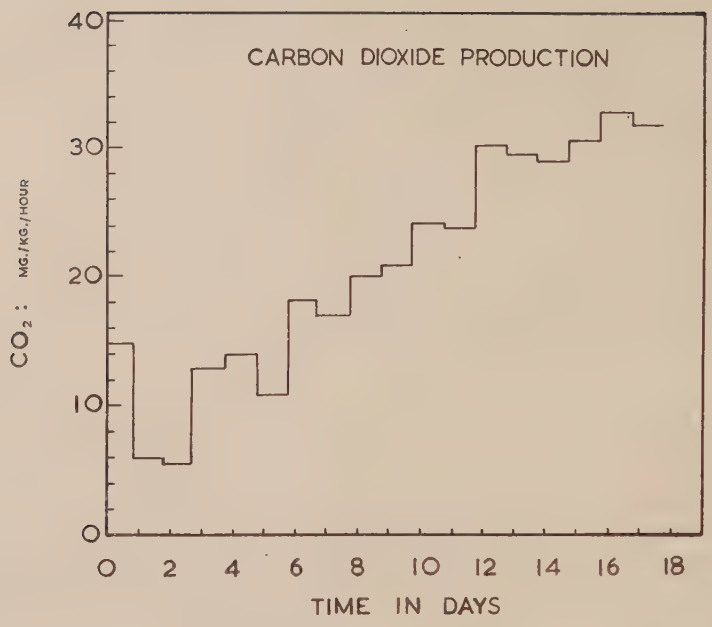
The fruit used was of the grades usually shipped to Great Britain (i.e., $\frac{3}{4}$ full) and to North America (i.e. heavy $\frac{3}{4}$ full). The storage period was a "voyage period", 12–18 days. The control of carbon dioxide and oxygen was effected by restricted ventilation, this being the only practicable method when fruit is stored on a large scale. The work was carried out in a cold store in Kingston, Jamaica. Metal cabinets to hold the fruit were specially designed to provide conditions which would approximate to those in the hold of a ship. The storage atmosphere was rapidly circulated and the stowage density was 198 cubic feet per ton compared with 140 cubic feet in hold storage. The rate of cooling was faster and the rate of accumulation of carbon dioxide consequently slower than it would be in a full scale cargo. Twenty-four experiments were carried out over a period of two years. A description of the methods and apparatus used and details of the results may be obtained in neostyled form on application to the Low Temperature Research Station.

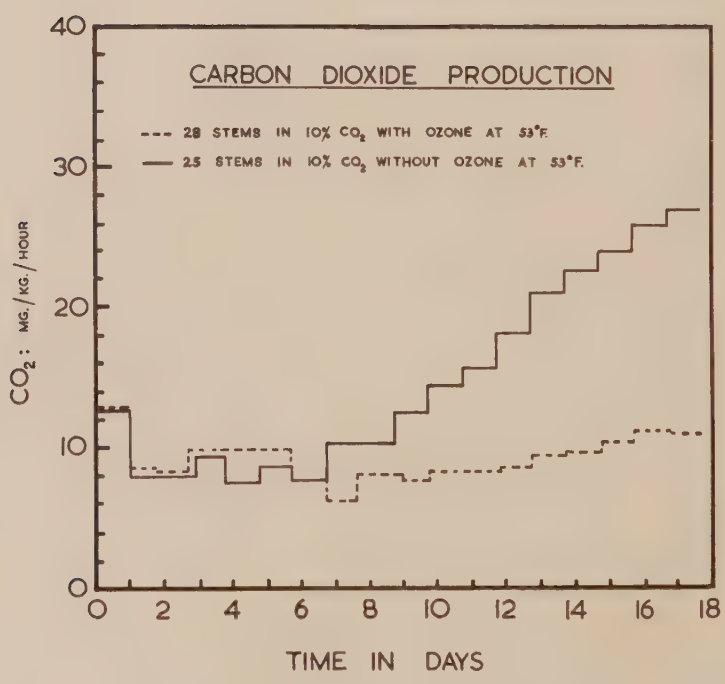
In the first series of experiments the rate of CO_2-production began to rise from the outset, thus indicating that the gas-storage conditions caused ripening to begin (Figure 1). Although ripening was evidently initiated, the gas-storage conditions retarded its progress. After storage for the "voyage periods" it was found impossible to ripen gas-stored bananas to good quality. Broadly speaking, these results are similar to those obtained by Wardlaw and his collaborators in those experiments in which ripening started either before or during the storage period. The conclusion drawn, therefore, was that when the scale is increased from that of a hand to that of a score of bunches and when no means of removing any accumulation of ethylene are provided, most of the fruit starts to ripen almost at once under the conditions of restricted ventilation used for gas-storage.* When a single hand was kept at 53°F. in a small glass container through which the required gas mixture was passed from a pressure cylinder, at a rate similar to the ordinary rate of ventilation of an air store with air, the respiration of the fruit did not rise, and the ripening of the fruit did not commence for at least 14 days.

A new series of experiments was then started to determine whether, on the scale of 20–25 bunches, the gas-storage atmosphere under conditions of restricted ventilation could be kept sufficiently free from ethylene to avoid the initiation of ripening, by introducing low concentrations of ozone. The results of this second series of experiments indicated that this was indeed possible. By means of ozone the content of ethylene in the gas storage atmosphere could be reduced without injuring the fruit. By employing ozone under gas storage conditions, "full $\frac{3}{4}$" grade fruit stowed as cargo was held for 20 days without any initiation of ripening, and subsequently was ripened at 68°F. to good quality.

Figure 2 illustrates the rate of CO_2-production in two gas-storage experiments with comparable fruit, in one of which ozone was used and in the

*The presence of bunches of fruit from plants infected with *cercospora* would be expected to increase the risk of including fruit likely to start ripening in storage.


CARBON DIOXIDE PRODUCTION
CO_2 : MG./KG./HOUR
0
10
20
30
40
0 2 4 6 8 10 12 14 16 18
TIME IN DAYS


CARBON DIOXIDE PRODUCTION
--- 28 STEMS IN 10% CO_2 WITH OZONE AT 53°F.
— 25 STEMS IN 10% CO_2 WITHOUT OZONE AT 53°F.
CO_2 : MG./KG./HOUR
0
10
20
30
40
0 2 4 6 8 10 12 14 16 18
TIME IN DAYS

other it was not. The rise in the rate of CO_2-production began in the latter case after 6 to 7 days ; in the former it had still not begun after 18 days, when the fruit was removed from gas storage. The fruit gas-stored without ozone could not be ripened to good quality whereas the fruit gas-stored with ozone ripened normally after treatment with ethylene.

The optimum conditions for gas storage of bananas have not been completely defined. It has been established that below 53°F. chilling injury will occur in 5 or 10 per cent. carbon dioxide, and that 10 per cent. is near the upper limit of concentration of carbon dioxide at temperatures in the range of 53–55°F.

Further surveys and experimental work on a pilot plant scale are necessary before the use of ozone either in refrigerated gas-storage or in refrigerated air-storage can be seriously considered. Ozone represents an additional variable. If it is present in too high a concentration it can harm the fruit, while if present in too low a concentration it may fail to produce the desired effect.

The great difficulty of interpreting the results obtained in the Jamaican experiments has been the doubt about the extent and effects of " Leaf Spot " infection. The uneven and erratic ripening of the fruit stored in air indicated that there was probably some infection. For further work on gas storage it is necessary to obtain fruit from plants free from " Leaf Spot " infection or to find some chemical test for diagnosing the effects of slight " Leaf Spot " infection.

The work described in this paper was carried out in Jamaica by staff of the Food Investigation Organisation of the Department of Scientific and Industrial Research seconded to the Colonial Office.

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Paper for publication No. L.T. 17/51*a*.

NOTES ON THE FERTILITY OF CACAO SOILS

(*a*) Diminishing Fertility of Successive Soil Layers
(*b*) Effect of Drying on Soil Fertility

By

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The decline in the productivity of cacao plantations in Trinidad is causing ever growing concern. The process has been in steady progress for the last 30 years and in some parts of the country has reached disquieting proportions. The causes are many. Hardy (1) in his survey of the problem lays great emphasis on the deterioration of cacao soils and their increasing inferiority as compared with virgin forest soils and is inclined to accept it as cause number one. Cacao, being genuinely a forest plant, with the bulk of its root system growing in the surface zone under the layer of litter, is particularly sensitive to any changes in the ecology of that zone (2, 3). Any factor which makes it resemble or differ from forest conditions must be responded to by the cacao plant.

A pot experiment described here demonstrates the rapidity of decline in cacao soil fertility with the depth of the profile. Two soils, representative of large cacao districts of Trinidad were chosen: River Estate Sandy Loam and Sangre Grande Silty Clay from Las Hermanas Estate, generally classified as medium-high quality and poor quality cacao soils respectively. The following soil layers were collected : litter plus surface soil-crumb material; 0–½ ins.; ½–2 ins.; 2–4 ins.; 4–6 ins. and 6–9 ins. The soil layers, before filling the pots, were passed through a ½ inch sieve. There was no difficulty with easily disintegrating River Estate Loam, but to carry out this operation with Las Hermanas clay, soil samples had to be completely dried, crushed and graded ; the ¼–½ inch fraction was used for the experiment. Cacao beans and Sudan Grass were planted.

Sudan Grass

This, having high requirements for available nutrients, responded soon after planting to differences in fertility of growing media as illustrated in Figures 1, 2 and 3. The decrease of fertility with depth of River Estate Sandy Loam is steady and gradual; it begins to be apparent even in the top ½ inch below the litter and surface crumb layer; below 4 inches the fertility becomes almost negligible. The effect of NPK mineral fertilizers, added to 4–6 ins. and 6–9 ins. layers is immediate; the growth of plants equals that in surface crumb soil material.

As Fig. 2 illustrates, the fertility status can be identified with adequate supply of nitrogen, the effect of potassium and phosphorus being unnoticeable.

Soil : River Estate Sandy Loam *Plant :* Sudan Grass

18 19 20 21 22 23 26 27

Pot 18—Litter + Surface Crumb Material
Pot 19—0–½ inch layer
Pot 20—½–2 inch layer
Pot 21—2–4 inch layer
Pot 22—4–6 inch layer
Pot 23—6–9 inch layer
Pot 26—4–6 ins. layer Received dressing of NPK.
Pot 27—6–9 ins. layer do. do.

Diminishing Fertility of Successive Soil Layers

Figure 1.

Soil : River Estate Sandy Loam Plant : Sudan Grass

18 19 20 21 22 23

Pot 21—Received a dressing of KCl
Pot 22—Received a dressing of NaH_2PO_4
Pot 23—Received a dressing of $(NH_4)_2 SO_4$

Diminishing Fertility of Successive Soil Layers

Figure 2.

Soil : LAS HERMANAS (Sangre Grande Silty Clay) *Plant :* SUDAN GRASS

Pot 3—Litter + Surface Crumb Material
Pot 6—½ inch top layer
Pot 9—½–2 inches layer
Pot 12—2–4 ins. layer
Pot 15—4–6 ins. layer
Pot 18—6–9 ins. layer

DIMINISHING FERTILITY OF SUCCESSIVE SOIL LAYERS

Figure 3.

In Las Hermanas clay (deteriorated marginal soil) the decline in fertility with depth is still more accentuated: at the depth of 2 ins. it is already at its lowest level. These results demonstrate once more the importance of the surface soil material and of the very top layer : if they are destroyed or removed the fertility may diminish to practically nothing.

Cacao Seedlings

Beans used for planting were of the same parentage from hand pollinated pods. There were three plants in each pot. Records of growth, i.e. height of plant and length of leaves, were taken, when the plants were about ten weeks old. Estimations of total nitrogen and phosphorus (extractable with Morgan solution) were carried out. Length of roots was measured and their weight (dry matter) estimated.

Table I. *Fertility of successive soil layers as reflected by the growth of cacao seedlings. Effect of diminishing fertility and of fertilizer treatment on the status of nitrogen and phosphorus in leaves*

Soil layer and Treatment	Height of Plant cm.		Length of Leaves cm.		% N in Leaves		% P_2O_5 in Leaves	
	River Estate	Las Herm.	River Estate	Las Herm.	River Estate	Las Herm.	River Estate	Las Herm.
Litter and Crumb ...	22.5	30.0	14.7	18.2	2.67	2.72	0.073	0.053
0–½ ins. ...	23.5	21.5	14.6	16.3	2.35	2.60	0.096	0.066
½–2 ins. ...	21.6	22.7	13.6	14.8	1.70	2.13	0.114	0.108
2–4 ins. ...	19.5	22.2	11.6	14.1	1.28	1.46	0.114	0.100
4–6 ins. ...	18.3	17.8	11.4	12.0	1.43	1.48	0.139	0.184
6–9 ins. ...	17.7	18.7	11.5	12.0	1.27	1.23	0.191	0.139
2–4 ins. + K	18.8	21.3	11.6	14.0	1.30	1.57	0.118	0.126
4–6 ins. + P	17.0	21.5	11.6	12.3	1.45	1.43	0.162	0.141
6–9 ins. + N	20.0	23.3	13.0	15.4	2.63	2.46	0.117	0.055
4–6 ins. + NPK ...	19.7	28.0	14.8	15.1	2.06	2.47	0.087	0.083
6–9 ins. + NPK ...	18.5	23.8	12.2	14.9	1.73	2.60	0.114	0.066

Discussion

The figures presented in Table I invite some attention.

(*a*) The growth of cacao seedlings, both stems and leaves, confirms the observations made on Sudan Grass (Fig. 1, 2 and 3), although for obvious reasons in not so conspicuous a manner. The diminishing fertility with depth is more accentuated in Las Hermanas soil (silty clay) than in River Estate Sandy Loam: in the 6–9 inch layer of the former soil the growth of plants is only 55 per cent., whereas in the latter it is 78 per cent. of the values for corresponding surface soil materials. Generally, however, the performance of plants grown in Las Hermanas clay was very much better.

(*b*) Plants grown in successive layers of Las Hermanas soil, which is generally considered to have very low fertility, had stems 16 per cent. higher and leaves 12 per cent. longer than those grown in River Estate Sandy Loam, of medium high fertility. Their general appearance was strikingly stronger and healthier ; their mean response to N and NPK applications, as shown by growth, was 31 per cent. as compared with 12 per cent. for plants grown in River Estate soil. The latter plants responded at first negatively to fertilizer treatment: general deterioration of growth appeared, accompanied by severe marginal leaf scorch. That difference in growth and health, in favour of "Las Hermanas" plants was not expected and a tentative explanation of its reasons will be given in paragraph (*e*).

(*c*) Single applications of N, P and K show that only nitrogen gives an improvement of growth. Potassium and phosphorus have no effect on growth, as with Sudan Grass.* This has been observed in other experiments (3). There is a close agreement between figures for growth and total nitrogen content in leaf tissues. It appears that nitrogen is the element controlling growth, at least in its initial period, and that plentiful application, rather commonly done, of phosphatic and potassic fertilizers may be highly uneconomical, particularly in the case of simultaneous heavy mulching.

(*d*) A curious and rather conspicuous interrelation appears in Table I between nitrogen and phosphorus contents in leaf tissues. Decrease in N content is almost invariably accompanied by proportional increase of P_2O_5; an application of nitrogen as fertilizer raises its content in leaf tissue and lowers the content of phosphorus. Figures expressed as percent. N and per mille P_2O_5 behave as complementary and their sums show a tendency towards a constant. This is shown in Fig. 4. The phenomenon is reported here without attempting an explanation. It deserves a separate and more systematic study.

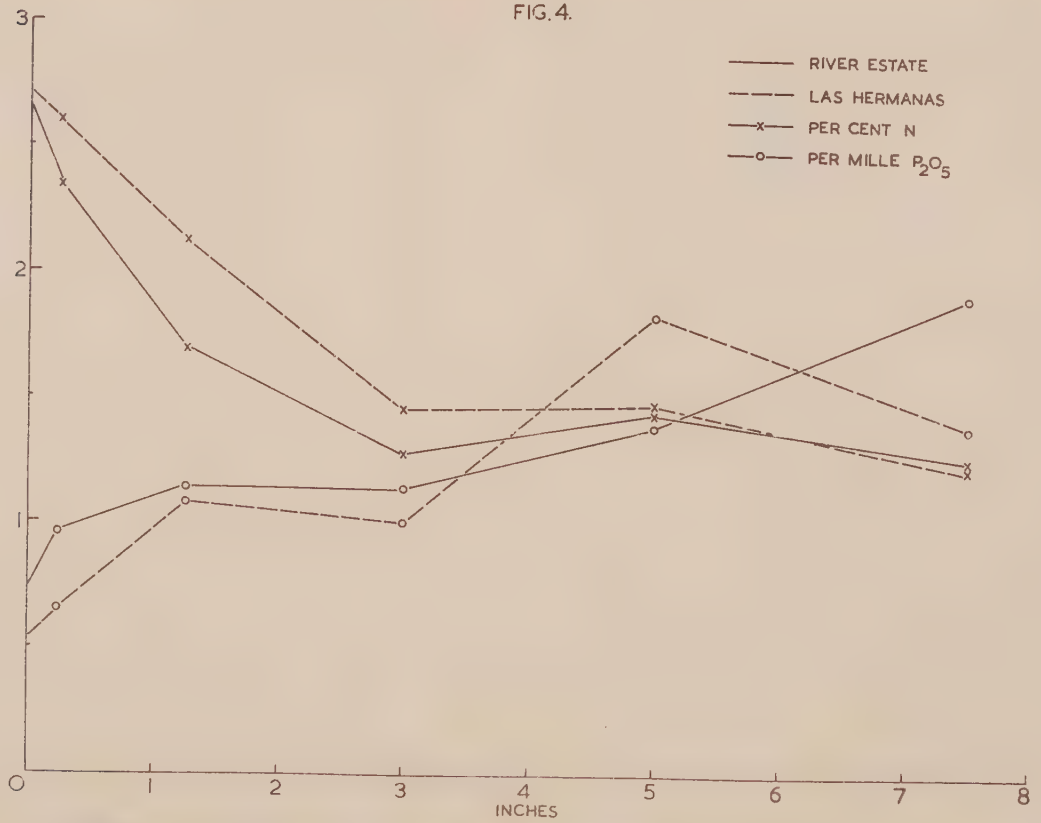
(*e*) As was pointed out in para. (*b*), the plants grown in Las Hermanas Silty Clay gave better growth than those grown in River Estate Sandy Loam, in spite of the higher fertility of the latter soil. The difference in general performance is summarised in Table II.

Las Hermanas clay was brought from the field in large, sticky, plastic clods. The only way to fill the pots with such material was to dry it completely in the sun and break it into small lumps. Broken soil was graded by sieves and the fraction of $\frac{1}{4}$–$\frac{1}{2}$ inch used. By this treatment a new factor was introduced—drying the soil, or in other words an artificial dry season.

The soils in the pots were watered daily with a gentle spray, which could be compared with daily heavy rain in nature. In these conditions the River Estate fine sandy loam lost its structure very quickly and became a uniform amorphous mass, whereas Las Hermanas clay retained its original lumpy character, free drainage and good aeration, in spite of daily watering for over five months. These features have been apparently responsible for better and healthier growth of plants and better utilisation of fertilizers.

*This has also been observed by F. Hardy in pot experiments with tomato seedlings, grown in various Trinidad soils (I.C.T.A., unpublished).

FIG. 4.



INTERRELATION BETWEEN NITROGEN AND PHOSPHORUS CONTENTS IN LEAF TISSUES OF CACAO SEEDLINGS

TABLE II. *A Comparison of Growth Records of Plants Grown in River Estate Sandy Loam and Las Hermanas Silty Clay*

		Plants grown in River Estate Sandy Loam		Plants grown in Las Hermanas Silty Clay	
Height of Plant		19.5 cm.		22.5 cm.	
Length of Leaves		12.7 cm.		14.2 cm.	
Dry Weight of Roots		1.71 gm.		2.03 gm.	
Length of Roots		36.0 cm.		40.0 cm.	
N content in leaf tissue		1.75 %		1.91%	
P_2O_5 content in leaf tissue		0.119%		0.107%	
		Height	Leaves	Height	Leaves
% Improvement of growth due to application of:	N	13	13	25	28
	P	—10	2	21	3
	K	—4	0	—4	—1
	NPK	5.5	18	42	24

DRY SEASON

One can make an attempt to translate the above observations into the field conditions. It is a common occurrence that heavy, clayey soils in Trinidad shrink so considerably during the dry season that wide and deep cracks are formed. There is also a general observation and conviction among the planters, that after a long and hard dry season the following crop of cacao, and also of sugar cane, is very good. Field observation, made at the peak of dry season in 1952 (March and April), revealed a profusion of new feeding roots developed in soil cracks. These observations allow an assumption that on the surface of clods formed by soil cracking particularly favourable conditions exist for root growth. F. Hardy (4) has discussed at length the problem of soil cracks in sugar cane soils of Trinidad and puts a considerable emphasis on their importance in air-water relations. To his preliminary survey of the problem one can add that in cacao soils, which are not cultivated, the cracking of the soil may be the only means of improving their physico-chemical and micro-biological condition and of increasing the availability of nutrients either present in the soil in an unavailable state or

added as fertilizers. There can be no doubt that due to deep cracking of heavy soils a complete shift from anaerobic to aerobic conditions, with all its consequences, takes place and may extend far into the wet season. In 1952, after a long and hard dry season, at the end of July, i.e. nearly two months after the onset of the rains, the cracks could still be traced in heavy clayey soils.

The beneficial effect of drying the soil in the laboratory or of its exposure to sun and dry summer weather in the field has been observed in countries of temperate climate. In Southern Italy summer cultivation has been practised since pre-Roman times and is based on an old belief that exposure of ploughed soil to summer sun increases its fertility. S. Campanile (5) in his study of these soils found a considerable increase of available potassium and decrease of acidity after gentle heating for several weeks. Aleksandrov (6) observed a positive dependence on dry weather of available potassium in Turkmen serozem under cotton. Most spectacular were the studies carried out by Lebediantzev (7) on Ukrainian soils (presumably tchernozems) some 30 years ago. He found that drying the soil increased yield from 11 per cent. (roots) to 329 per cent. (meadow plants). In soil extracts he observed an increase of: organic substances 50–500 per cent., mineral substances 10–20 per cent., total N 30–300 per cent., total P_2O_5 50 per cent. and more, ammonium N 10–15 times and a decrease of bacterial population 3–5 times. He concludes that " drying is one of the powerful factors which help to transform the fertility elements of the soil from a potential to an active form." And that applies both to greenhouse and natural conditions.

Practical Conclusions

It seems to be of primary importance to extend, by suitable and available means, the effects of the dry season for as long as possible after the onset of the rains. In heavy alluvial clays of the Northern Plain of Trinidad, conditions of impeded drainage and of water-logging prevail. The first rains begin to fill the soil cracks, causing the lower soil layers to absorb rain water beyond sticky point. This may lead either to severe land slides or to swelling up of the whole mass of soil and to the return of anaerobic conditions. The beneficial effect of the dry season is then lost.

As the described experiment has shown, Las Hermanas silty-clay, after having been dried, is able to retain its lumpy structure for a very considerable time, in spite of heavy watering, provided the drainage is free. If conditions of free drainage and quick outlet of the excess of rain water, preventing its stagnation in soil cracks, could be secured in practice, much of the beneficial effect of the dry season would extend far into, or throughout the rains. Much of this could be achieved by digging trenches at the right time, i.e. at the beginning of the rains, when the soil cracks are still open and the soil moist enough for the use of implements.

In the author's opinion the effect of the dry season on soil fertility is one of the most important problems awaiting a special and thorough study both in the field and in the laboratory.

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THE EFFECT OF MULCHING ON THE STATUS OF MAJOR NUTRIENTS AND THE GROWTH OF CACAO SEEDLINGS

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Summary

A pot experiment with cacao seedlings grown in soil under various mulches is described. Considerable decrease of nitrogen content and increase of phosphorus and potassium in leaf tissues due to mulching have been observed. Similar observations have been made with regard to N, P and K content in percolates. Discussions of these phenomena are presented. Emphasis is laid on changes in the ecology of the surface soil layer, favourable to root growth, brought about by mulching.

Introduction

For about two decades the problem of mulching has been receiving ever-growing attention by research workers and farmers. Its bibliography has reached considerable proportions and has been several times shortly reviewed (1, 2, 3). Although application of mulch in some parts of the world is an established practice (4, 5), recognised as highly beneficial to soils and crops, and has gained steady supporters (6), in others it has met with criticism, mainly on economic grounds, or has received recognition only as a supplier of easily available plant nutrients (7), primarily nitrogen (8). From the research work done hitherto it appears certain that all kinds of mulches introduce profound changes in the physical, chemical and biological conditions of the soil. These, however, in their high complexity may not always be beneficial to crops. These changes might be summarised as an introduction of new life to the soil and of new ecology to its surface layer (9, 10), which in ever increasing areas of marginal or deteriorating soils in the tropics (11) and for surface-rooting crops like cacao may be a *sine qua non* condition of success.

The experiment described here had as its aim to examine and demonstrate the influence which various mulches exert on major-nutrient status and growth of cacao seedlings in uniform and controlled conditions of moisture and environment.

Methods and Materials

Plants were grown from seeds in Mitscherlich pots in soil (River Estate Sandy Loam), which received a uniform dressing of NPK: 3.7 gms. NH_4Cl, 1.7 gms. NaH_2PO_4, 4.0 gms. K_2SO_4, per pot, which corresponded to heavy dressing of 11 cwts. of sulphate of ammonia, 14 cwts. of superphosphate and

10 cwts. sulphate of potash, per acre. The treatments included bare soil and mulches of bagasse, grass (Sudan grass), sawdust, gravel and waxed paper. Organic mulches were applied at the time of planting and at the rate of 200 gms. per pot, which equalled 25 tons of air-dry matter per acre.

Equivalent of mineral constituents applied as mulches

	Total N (gm.)	Total Ash (gm.)	P_2O_5 (gm.)	K_2O (gm.)
200 gm. bagasse	0.318	5.46	0.116	0.238
200 gm. grass	0.970	15.64	0.864	1.884
200 gm. sawdust	0.244	2.24	trace	0.254

The pots were arranged in five randomised blocks, i.e., six treatments in five replications. There were three plants in each pot.

When the plants reached the age of 6 to 7 months, six top mature leaves were collected for analysis. Total nitrogen, total potassium and extractable phosphorus were estimated: nitrogen by Lindner's micro-method (12), potassium flame-photometrically in sulphuric acid digests and phosphorus colorimetrically in Morgan solution extracts.

Effect of Mulches on Major Nutrient Status in Leaf Tissues

TABLE I

Total N, extractable P and total K in leaf tissue.
(Per cent. dry matter)

Treatment	Bare soil	Bagasse	Grass	Sawdust	Waxed paper	Gravel	Significant difference P – 0.01
N	2.02	1.16	1.40	1.28	1.60	1.48	0.41
P	0.052	0.061	0.074	0.073	0.063	0.049	0.0128
K	2.29	2.61	2.56	2.54	2.51	2.31	—

Discussion: Much work has been done on the close agreement between the results of foliar analysis and the availability of nutrients in the soil, so that the assumption can be made that the nutrient status in the plant is a fair reflection of what happens in the soil. On this assumption the following discussions are based.

Nitrogen: There was a very considerable and highly significant lowering of nitrogen content under all mulches and particularly under bagasse and sawdust. The latter two treatments caused visual symptoms of severe nitrogen deficiency in spite of the heavy initial dressing of ammonium chloride. The suppression of nitrogen availability by organic mulches, particularly those having high C/N ratio, is not a novelty and has been observed by many investigators (4, 13, 14, 15, 16, 17, 18, 19, 20). The causes

of this phenomenon are variously explained: by exclusion of air, which brings about a deficiency of soil oxygen and suppresses nitrification (19): by exclusion of light, which is also claimed to affect nitrification (17) ; by formation of soluble organic nitrogenous derivatives leached into the soil (14) in a form unavailable to plants, although the latter view conflicts with observations made on the availability of such compounds (21, 22). All mulches, and primarily organic ones, create on the surface of the soil a new micro-climate and new environmental conditions, optimal for rapid development of both micro-flora and micro-fauna, which may "lock-up" nearly all available nitrogen in their bodies and compete successfully with higher plants (13, 16, 20).

Phosphorus: There was an increase of this element in plants grown under organic mulches; highly significant for grass and sawdust and significant for bagasse at P = 0.08. The most probable explanation of this phenomenon seems to be the release of fixed phosphate-ion by organic compounds, penetrating into the soil in course of the decomposition of mulch, and by higher microbial activity (20, 23). This effect of organic matter on the availability of soil phosphorus has been observed by various workers (24, 25, 26, 27, 28, 29, 30). Wander & Gourley (31) found a ten-fold increase of available phosphorus in the top 3-inch soil layer under straw mulch and also an increase of phosphorus content in leaves and fruits. Chaminade (27) in his studies on Madagascar soils showed that added phosphate was not available to plants unless the soil was treated with calcium-humate. Steady increase of available phosphorus in the soil under grass mulch is reported from Trinidad (9).

Potassium: The results of leaf analysis do not show any significant difference in potassium content between treatments, although there is a definite suggestion of an increase of this element due to organic mulches. Apparently there was ample supply of available potassium in the original soil and from the NPK treatment to satisfy the requirements of the plants. An increase of available potassium in soil and in leaf tissues, brought about by mulching, has been reported by many workers (4, 5, 33, 34) and is strikingly confirmed by the analysis of percolate in this experiment (Table IV). Wander (31, 32) found a very considerable increase of available potassium to a depth of 24 ins., as a result of straw mulch; Baker (35, 36) was able to correct potassium deficiency in peach trees by application of organic mulches; Holmes (37) reported an increase of potassium content (about 50 per cent.) in fruits of tomatoes grown under straw and sugar cane mulches. Mulching experiments in Trinidad (9) also show from year to year, a considerable and steady increase of available potassium in the soil under grass mulch. E. J. Russell (1) in his summing up of the problem says "extra uptake of potassium and possibly also of phosphate appears to be a specific effect of the mulch" and adds "due to some cause yet unrecognised . . . . . ." (p. 587) but elsewhere (p. 110) gives a tentative explanation : "Potassium fixation is enhanced by repeatedly wetting and drying" the soil. This is a common occurrence in the tropics during dry and intermediate seasons in unprotected soil.

Effect of Mulches on the Growth of Cacao Seedlings

Records of growth were taken when the plants were 10 months old. The height of plants was measured from the base to the apex of the stalk. The product of the length and width of the leaf was accepted as representative for " leaf size " ; three top mature and hardened leaves were measured on each plant. The figures in Table II represent means for 10 plants.

TABLE II

Growth Measurements of Cacao Seedlings

Treatment	Bare soil	Bagasse	Grass	Sawdust	Paper	Gravel	Significant difference P – 0.05
Height of plant, cm.	62.4	49.6	54.8	47.6	62.6	56.0	2.16
Size of leaves ...	159	141	156	153	183	176	—

Discussion: The height of plant was strongly affected by organic mulches (and gravel mulch), particularly by sawdust and bagasse. There is a fair parallelism between the height of plant and N-content in leaf tissues (Table I). Apparently a good supply of nitrogen is the first condition of growth of cacao seedlings in their early stages. The leaf size does not seem to be affected by the treatments. Although there is a slight suggestion of a decrease of leaf size under organic mulches, particularly under bagasse, the differences are non-significant. The general appearance of leaves and the quality of tissue, however, were always " poorer " under organic mulches and " better " under paper, gravel and in bare soil.

Effect of Mulches on Root System

TABLE III

Root Growth Measurements on Cacao Seedlings

Treatment	Bare soil	Bagasse	Grass	Sawdust	Paper	Gravel
Length of roots: cms	42.2	59.2	52.2	51.4	46.2	64.0
Weight of roots: gms	4.44	5.54	5.34	4.80	6.88	7.56

Discussion: There was a general tendency towards the increase of both length and weight of roots under mulches. In the pots with organic mulches the top roots were growing within mulch itself, above the soil.

The differences in root systems are doubtless due to favourable changes in soil physical conditions, which take place under mulch. Stephenson (33, 34) found a ten-fold increase of water-stable aggregates, larger than 1 mm., in soil under straw mulch, and Molina (38) experimentally proved that resistance of soil aggregates to the attack of rain drops increases ten times after addition of organic colloids produced during decomposition of cellulose in aerobic conditions; the increase of the rate of percolation due to mulches was proved by Turk (4) and Rule (39); and deeper penetration of rain water by Pereira (40) and Karnaukov (41). The increase of soil moisture and levelling of the extremes in soil temperature are well known results of mulching and have been often reported.

All the effects of mulches reflected in changes of physical and chemical conditions, among which the increase of available phosphorus may play an important part (Table IV), " help to maintain the surface layer of the soil as a suitable environment for root growth" (Russell (1), p. 587). For shallow-rooting or surface-rooting crops like cacao this is of primary importance.

Influence of Mulch on N, P and K Content in Percolates

TABLE IV

N, P, and K Content of Percolates

p.p.m. in percolates	Bare soil	Bagasse	Grass	Sawdust	Paper	Gravel	Significant difference P–0.05
Nitrate-N	67.6	—	—	—	31.8	47.7	—
P_2O_5	0.41	0.59	1.03	0.90	1.07	0.97	0.49
K_2O	357	892	1077	772	315	419	68

Table IV gives results of analysis of percolates from the pots. Nitrate-N was estimated colorimetrically (42) and potassium flame-photometrically in original percolates ; phosphorus colorimetrically after evaporation and removal of soluble and colloidal silica.

Discussion: Noteworthy is a complete absence of nitrates and a very considerable and highly significant increase of potassium in percolates from pots with organic mulches. There is also an increase of soluble phosphates under all mulches as compared with bare soil. The results agree with, and confirm, the points discussed under Table I.

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A RECONNAISSANCE SURVEY OF LAND UTILISATION ON AN AREA OF THE NORTHERN FOOTHILLS OF TRINIDAD

A Summary of Unpublished Reports[1] *by* R. A. SANDS[2], J. S. URE[2], AND I. WILL[2]:

BY

G. ap GRIFFITH[3]

THE Northern Range of Trinidad occupies a rectangular area some ten miles of width bounded on three sides by the sea and sloping on the southern flank to the northern plains. It is extremely dissected by valleys running north-south which in the east of the range are narrow and precipitous but widen to the west. The valley bottoms are in fairly intensive agricultural use. The slopes were once planted with cocoa (up to 1,500 ft. in many parts) but the cocoa plantations have now largely receded and the "high tide" is marked only by surviving Immortelle shade trees (*Erythrina micropterix*).

The whole area comprises about a fifth of the total area of Trinidad and is the only large undeveloped area which offers any possibilities for food crop production.

At the foot of the southern flank urbanisation has spread westwards and eastwards from Port-of-Spain until there is now a ribbon strip of urban and suburban development extending half the width of the island. To meet the food needs of the population of this strip cultivators have attacked the hillsides and in patches, such as the one studied, have gone up to over 1,500 feet on slopes up to and over 40°. No conservation measures are used and the conclusion appears self evident—catastrophic erosion. In fact erosion is not nearly as serious as one could expect and for this Trinidad may thank her luck that her rainfall, though heavy, is well distributed over the eight rainy months and seldom sustains torrential intensity for more than several minutes. Again the parent rock is well jointed and porous. In Africa such slopes cultivated in such a completely haphazard way would last no more than a year or two in cultivation. These slopes have been cultivated for twenty years and are still producing, though soil losses must be considerable. There has been no attempt at a systematic survey so that virtually nothing is known of yield levels and whether or not they are declining, but it must be assumed that they are still sufficient to justify the labour of climbing and tilling these steep slopes. To some of these cultivators it is Hobson's choice as they claim that one of the factors which drives them up the hills is the fear of loss of their crops by theft (one of the big handicaps to agricultural development in the

(1) Available for reference from the Library, I.C.T.A.

(2) Post-graduate students—The Imperial College of Tropical Agriculture.

(3) Reader in Soil Science & Chemistry—The Imperial College of Tropical Agriculture.

West Indies). The cultivators pay a far from nominal rent to a landlord whom in many cases they never see and who has no interest in the land beyond the rent his agent collects.

In the area studied there are also plantation crops, mainly cocoa. It is suggested that the dense shade cast by closely growing cocoa and its shade trees constitutes a danger on steep slopes through the suppression of ground vegetation.

Run off from the peasant cultivations is loosely blamed for the increasing hazard of flooding on the plains but there are no measurements to support this view, and it is likely that a great part of the fault lies in the roads and roofs of the suburban ribbon.

The whole area of which this is a sample constitutes a valuable reserve of potential food producing land and it is a matter of urgency that a survey of it should be undertaken and that the necessary steps should be taken without delay to introduce to the cultivators and landlords the necessary aids —and penalties. Complacency is erosion's strongest ally. Part of the area surveyed forms a convenient topographic unit for measurement on a realistic scale of run off and erosion and also for a study of the social and agricultural implications of conservation measures. The suggestion put forward by Cater (1) that all land above the 300 ft. contour should be allowed to revert to forest is thought to be somewhat unrealistic but the feasibility of this and/or any other schemes can only be properly estimated by a full survey of the area.

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UNIT FARMS

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Introduction

An investigation into systems of peasant agriculture has been in progress at the Imperial College since June, 1946. During the investigation considerable experience has been gained about the unit farm technique. The object of this article is to summarise this experience and lay down some principles for the successful application of the technique.

Although the College units are designed to investigate individual peasant farming systems the technique is applicable to almost any type of agriculture. For example, the committee responsible for the investigation has been consulted on the applicability of units to group farming ; its conclusion was that unit farms could be designed which would satisfactorily represent conditions applying to a large, highly organised group. Individual peasant farms are however likely to provide the most fruitful field for investigation for some years to come because the scope for improvement is so large and the cost of the simple units required comparatively low.

Experimental versus Demonstration Units

It is common when projecting a unit farm investigation for no clear distinction to be made between experimental and demonstration farms. The two are contradictory and cannot be combined in one unit. If, as should be, the object of the investigation is to evolve by practical experimentation an improved system of farming the unit cannot demonstrate any successful system until the experiment is concluded. An experimental unit is essentially dynamic ; a demonstration static. The notes in this article refer to experimental units.

An experimental unit should as far as possible be hidden from public view. Commercial farmers, and agricultural extension officers sometimes do not understand why certain techniques have to be employed and are in danger of concluding that a unit has little relation with reality. On the other hand they may be impressed by some agricultural feature which is under test on the unit ; they may wrongly assume it to be a proven technique and apply it indiscriminately elsewhere. The lack of value of an experimental unit as an implement of extension work must be faced by any agency setting up such units. The first published report on the College investigation is only now in preparation, 6½ years after its inception.

Objects and Conditions

There is sometimes confusion between the object of a unit and the conditions under which the object is to be achieved. There is in fact only one object of any unit holding ; it is to obtain the highest permanent net income possible. Net income is used in the widest economic sense to include capital changes and charges. Any qualification of their object must be regarded as a condition under which it is to be achieved.

It is wise before any farming operations commence, to decide what are the minimum earnings for a unit to be considered successful. If no such minimum is laid down there is a risk of the investigation not being carried far enough. Any rate of earning higher than the lowest that can be instanced among ordinary farmers of the district is liable to be considered a satisfactory level. The satisfactory level should be determined by the highest, not the lowest, earnings of the district because the investigation is presumably undertaken on the assumption that there is scope for improvement of earnings. In the College investigation the minimum standard is full-time wages of a man and woman (the unit) although few peasants have incomes as high and few labourers obtain full-time employment. This level ensures that a satisfactory system will yield earnings high enough to remove the common temptation of farmers to become involved in activities other than farming their holdings. In areas where there is no alternative employment to farming the minimum earnings can be calculated from satisfactory standards of diet, housing, clothing, &c.

The conditions under which this object is to be achieved can vary widely and are difficult to define. They need detailed consideration. Their choice depends on the type of farming which is most worthy of investigation. Most commonly the investigation is prompted by the apparent possibilities of some crop or farming technique not at present practised by surrounding farmers. In Trinidad, for instance, mixed farming in the sense of keeping livestock partly to produce manure to be applied to the land is rarely practised. A condition on all the arable unit farms there is that mixed farming shall be practised. This condition imposed others. Every holding must have a supply of fodder and an area of land, sometimes in rotation with crops, is reserved for grass. Concentrated feeds are usually necessary, but no condition is imposed on the source of these concentrates because in Trinidad the most economical rations are obtained by purchase. Livestock cannot be left untended and the condition is laid down that the workers must live on the unit holdings.

Some of the likely conditions imposed on unit farms may now be considered. A common condition is that a farmer should raise his own food. If this condition is made an estimate must be made of what food is required during the year, how long various products can be stored, &c., and from the findings a cropping plan prepared of the areas required to provide subsistence. The general condition of subsistence farming would not allow surplus production of one crop to be set against the deficiency in another ; the need for imposing the condition is presumably that transport and marketing conditions do not permit trade in food crops.

Another common condition is that the holding shall be worked by hand because such a holding is cheapest from the point of view of capital and least demanding in skill. It has therefore wide application among less advanced people. If this condition is strictly adhered to the possibilities of the holding may be severely limited and it is often necessary to qualify the conditions somewhat. The qualification may be that transport service is provided for some produce and this service will require careful definition. The worker on the unit may be required to carry or head his " export " produce (and/or supplies) a certain distance representing the average to some line of communication on which transport is provided. On some manual holdings it may appear desirable to provide mechanical service for some field cultivation. This qualification is most difficult to apply fairly to one unit holding. It is very easy to provide for instance, a ploughing service for one farm always at the right time of the year whereas it is unlikely that such ideal service would be available for ordinary farmers.

Full-time employment throughout the year is another condition that is commonly imposed. The reason for such a condition is usually that a farmer is likely to be more efficient if he is working on his farm all the year than only seasonally. The achievement of full-time employment may involve enterprises which by themselves are not profitable. (On the College units where this condition is imposed such unprofitable production has proved to be unnecessary). It may sometimes be difficult to decide what is unemployment and what is unprofitable occupation. Decisions and rulings must be made.

If a limit is placed on the amount of capital available to establish the farm, the accounting will be somewhat complicated. The complication is that recapitalisation is often necessary in order to modify the system of farming as the experiment progresses. It is however quite possible to write off redundant capital but obviously detailed valuations and accurate capital accounts must be kept if this condition is imposed.

The common condition that is likely to grow up during the course of an investigation, if it is not actually imposed from the beginning, is the area of land available for the unit. It is very undesirable that any fixed acreage should be specified although a ceiling may be placed on the total or a floor on the average output per acre. There is little justification in any territory for insisting that only a fixed and probably sub-adequate area of land is available per head of population and a unit farm must evolve the highest income from this area. The paramount problem of a community in such circumstances is probably not evolving the most productive farming with everyone employed in agriculture but of obtaining alternative employment to remove some of the excess pressure from the land. A unit farm should therefore be laid out with plenty of spare land for expansion.

To ensure that an experimental unit offers wide scope for development as many factors as possible should be kept flexible within the definition of conditions of the holding. On the units in Trinidad no limit is placed on the

area of land provided that the gross output per acre is more than $250 (about the average of sugar estate land) ; no limit is placed on the purchase of fertilisers or feeding stuffs to the limit of their profitable application ; on the amount of any one type of produce raised, (within the condition of mixed farming) ; on capital within the limits of profitable application and other conditions of the holdings.

Original Design

A good deal of hard thinking is required in planning the original design of the unit holding. It is usually inadequate merely to copy farming of the surrounding district with a few minor modifications. The justification for an experimental unit farm is that there is some major opportunity of improving the system of farming in the district. The surest way of proving whether this opportunity can be realised is to design a holding purposely to exploit it to the full. There are few advantages and many handicaps in starting an experimental unit on the existing system of farming to show step by step how it can be modified to a better one.

The investigation in Trinidad has proved to be a good example of how unit holdings should not be designed ; their development from a system comparable with surrounding peasants has admittedly had some educational value in a teaching College but this value has hardly been commensurate with the labour and delay of redesigning established holdings. The arable holdings in Trinidad in their original form were farmed on a rotation that combined short term crops such as maize, sweet potatoes and legumes with yams and sugar cane. The original rotation occupied no less than nine years and produced six different crop products. This rotation from its very complexity handicapped the experiment from the start ; it is well-nigh impossible to make changes in the cropping when the whole system is based on such a complicated, long term plan. The incorporation of all the common peasant crops of the neighbourhood into the rotational system was based from faulty reasoning.

Experience has shown that the reasoning should have been on different lines and a different crop plan would have resulted. The major opportunity for improved peasant farming on this particular land appeared to be the introduction of mixed crop and livestock farming. Assuming this, the cropping of the holdings should have been designed to make the maximum productive use of pen manure. Of all the local crops yams respond most to pen manure. A corollary to mixed farming is that the peasant must be a full-time worker on his holding. The labour requirements of yams should then have been considered and see what other crops were necessary to provide uniform labour requirements throughout the year. The characteristic of yams is the heavy demand for labour at the beginning of the growing season and comparatively little work at harvesting. The complementary crop from the point of view of labour is not short term annual crops which have similar demands but sugar cane which makes the heaviest labour demands in the harvesting season.

The experimental arable holdings were continued unsatisfactorily for three years because only minor modifications were possible with such a complicated original rotation. These modifications were quite ineffective in exploiting the possibilities of mixed farming to the full. After three years it was necessary to scrap the original rotation completely and in effect to start the experiments over again on cane and yams.

Remuneration of Workers

The method of remunerating man power on an experimental holding has in the past probably been the chief reason for a failure of such experiments. The failure is often attributed to " the failure of the human factor " ; but is really due to confusion between the demonstration and experimental holding ; and an effort to make the man-power appear to be similar to an independent peasant. The experimental holding is an experiment essentially in management and management cannot be contributed by the individuals who merely supply the man-power to operate the farm. The "peasant" on an experimental holding must be an employee.

The objection to paying wages to workers on experimental units is that they will not work as hard or with such care as a small man operating his own farm. This may be if the right kind of incentives are not offered but the alternative of rewarding a man by the results of the holding takes the managerial discretion out of the hands of the investigators.

In Trinidad a number of different methods of rewarding workers on experimental units have been considered and tried and only after five years has the ideal been evolved. Originally there was strong feeling that the bulk of the workers' earnings should be related to the produce of the holding. As a compromise the original system was to pay them wages and in addition 25 per cent. of the gross value of produce raised. It soon became apparent that this percentage was an unworkable method of awarding incentive bonuses because different experimental units from their very organisation had different gross outputs.

A bonus based on net output is no better. No worker will be satisfied with a computation of net output which is determined partly by the direct inputs and capital depreciation over which he has no control. Workers naturally object to the imposition of a higher standard of management than they think necessary. For instance, in computing the net output from milk production a worker may object to deduction for concentrated feed stuffs supplied. He would probably object to a prohibition on his selling milk retail. He would object to using milk for calf raising when he could obtain an immediately higher income by selling the calf and selling the milk that would have been otherwise consumed. In short a bonus payment on produce interests the worker too closely to the management of the unit and so handicaps the experiment.

The second system of incentives tried at the College was to mark workers monthly on the degree of co-operation they showed in the experiment, the

condition of their livestock, crops, &c. These marks were used to compute the bonus payment at the end of the year. This system was found to be defective because the annual payment of a comparatively large sum did not give the day to day incentive. The worker usually resented any deduction of marks although early in the year he often did not exert himself unduly to earn them. This annual lump sum was intended to represent conditions comparable with an independent peasant whose earnings would be highest at the end of the harvesting season. There seems no advantage, however, in attempting to represent this condition and much to be said against it.

The system which has worked satisfactorily for the last eighteen months is to pay an incentive bonus based on the above considerations but on a day to day basis with the wages. Any lack of co-operation, work poorly done or failure to observe some obvious fact results immediately in a deduction of bonus. Recently bonus earnings have been consistently high because admirable co-operation and keenness has been attained by the system. The fact that the workers can see, pay day by pay day, that they are earning more than ordinary employees promotes their interest in the investigation.

From experience at the College it may therefore be said that the difficulty of the human element can be overcome by paying the workers current wages plus a *daily* incentive bonus awarded for diligence and co-operation in the experiment.

Establishment of Holding

The method of establishing the holding must be decided before work commences. The question is how much of the establishment should be done for the peasant and how much left for him to complete. It is often presumed that the worker should reproduce peasant conditions by establishing the holding himself. This is necessary only where the experiment is laid out with the object of determining how best an individual with a given amount of capital can establish himself as a farmer. More often the purpose of the experiment is to evolve a more productive type of farming. In such an experiment there is no virtue in the worker doing all the establishment and such a policy only delays and confuses the evolution of the farm. The worker should be employed on establishment only so far as it is desirable to test his abilities as a future worker on the holding.

If it is agreed that the holding should be established in the quickest possible way the question arises how far the initial establishment should be carried. Complications will arise when semi-perennial crops are grown if the entire intended acreage is established at the outset. On the Trinidad units the whole cane acreage was not established for the farmer ; if it had been, the results for the first few years would appear unduly good because he had an unduly large proportion of young cane. Whatever proportion of the final holding it is decided to establish to begin with, careful accounting must be practised ; young crops of sugar cane are not really more profitable than old ratoons if a proper rate of depreciation of the planting costs are charged against harvest.

A method of establishing the holding should therefore aim to get the experiment running on the lines of the intended design in the shortest possible time. The means by which this object is achieved must be within practical possibilities if the capital requirements of the unit are considered ; for instance, a tractor may be available for establishing one experimental unit but mechanical power for such purposes may not be available for a large number. If this is the position the unit holding should be established with hand labour. In the same way the cost of planting material and livestock should be calculated on the likely cost for a large number of units, although the requirements for one unit can often be obtained cheaply from the surplus of other farms.

Operation of the Holding

The most difficult period of an experimental holding is during establishment and the first few months of operation. It is necessary at this time that a senior officer who has probably played a large part in designing the experiment shall be constantly available. He will be capable of recognising flaws in technique of establishment and operation and can modify them before they become permanent faults. One feature that should constantly occupy his attention are the records collected. Only a senior officer can decide whether it is worthwhile measuring or weighing any particular material entering into the farm operations. In the first months he should evolve a recording system which can then be adequately carried on by juniors.

Careful accounting is the essential feature of an experimental holding. A system of record sheets by themselves has proved inadequate to obtain the required information. Accounting has the advantage that it is designed primarily to give a compact statement of the overall profitability of the farm taking account of changes in capital values. Since the object of the investigation is to obtain the maximum earnings for the hypothetical operator the calculation of profit by sound accounting is the essential yardstick of success.

The accounting must also be very detailed. There will be little outside information in the first years of the problems and opportunities that are likely to arise. Very full factual information is required so that any difficulty or possible opportunity can be investigated from the past working of the unit. A system that maintains the essential principles of accountancy but at the same time makes a great amount of detail readily accessible has been developed at the College.

The amount and calibre of supervision required in the early stages of a unit farm make it undesirable that many should be started simultaneously. The four units at the College originally covered only twelve acres but have on occasions in the early stages severely taxed the supervisory staff. It is often possible to design one basic holding as the essential first step in investigating farming in a particular district. Subsequently other holdings embodying

some refinements and usually requiring more capital can be started ; the design of these will be greatly improved by the experience of the basic holding. On the three arable units in Trinidad the manual-arable holding was commenced one year before the other two. It would probably have been better to continue the basic manual holding for at least three years before attempting the other two more elaborate ones.

The supervisory work on unit holdings gradually decreases as the methods of management become more definite. It is rare however, that a system will prove itself in three or four years, unless it is a failure. Anything up to ten years should be budgeted for the completion of a unit holding investigation. When the system and earnings of the holdings have been finally ascertained, the holdings, which should by then more than pay their way, can be inexpensively continued as demonstration farms.

It has been realised at the College that there is a very real extension problem in inducing ordinary farmers to practise a system that has been proved superior on the unit farm. The problem is not merely in " getting the story over " to farmers but convincing them that the capital required to practise the improved system is essential and therefore sacrosanct. Every farmer in difficult times is tempted to encroach on his capital by selling stock, failing to replace assets or farming at a lower standard than the system requires. Such encroachment is agricultural and commercial suicide. The only way of solving this extension problem seems to be by establishing experimental settlements. Such settlements will have to be carefully controlled in the early years to ensure that the proven system of farming is followed to the letter. The terms on which settlers may occupy land will be severely restricted to ensure that it is farmed as intended. It is hoped that the increase in prosperity of these settlers will be the best method of convincing neighbouring farmers that the proved system is the most rewarding one.

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ESTATE FERTILISER TRIALS ON COCONUTS IN TRINIDAD

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Summary

Five non-statistical fertiliser trials laid down with coconuts growing under estate conditions are described.

A severe dry season overrides all fertiliser treatments and the fall in yield is proportional to the initial level of bearing of the tree.

In two of the trials increased numbers of nuts were secured from applications of sulphate of ammonia. The response is proportional to the initial level of bearing of the tree, poor bearers showing a greater increase in yield than good bearers. Under such conditions differential fertilising should be practised, only poor yielders being treated in the first instance.

No response was found to applications of potash or phosphate in the absence of nitrogen but trials would need to be run over several more years before definite conclusions could be drawn, particularly in regard to copra per nut. With normal yields of 80 to 100 nuts per tree, fertilising with N, P, and K gives no increase in yield, other factors probably being limiting.

The difficulties involved in fertiliser trials with coconuts are summarised and the need for simpler alternative methods of assessing nutritional requirements discussed.

Introduction

Coconuts occupy some 40,000 acres of land in Trinidad, the crop ranking next to sugar and cocoa in the island's agricultural economy. With the large increases in yield that have resulted from the systematic use of fertilisers, particularly ammonium sulphate, on such crops as sugar cane and citrus, it was of interest to know whether similar results could be obtained with coconuts.

Apart from studies made by de Verteuil (1934) and Bain (1937) on the effect of fertilisers on the Bronze Leaf Wilt disease of coconuts, little was known of the responses, if any, of coconuts in Trinidad to fertilisers. Accordingly, in 1946, the first of a series of trials was started by Dr. E. Phillis, then Chief Scientific Officer of the Department of Agriculture, on the effect of manures and fertilisers on the yield of estate coconuts.

Coconuts are grown in Trinidad on a wide range of soils varying from the sandy fringes of the beaches to the heavy inland clays, and the first two trials were planned for estates on a sandy alluvium and clay soil respectively. The difficulties involved in using a statistical layout for trials on coconuts are considerable and one factor alone, the expense of picking and recording the yields of possibly 15 or 20 acres of coconuts over several years, precluded the standard statistical layouts. It was thought worthwhile, however, to lay down non-statistical trials on several estates which might give an indication of the potential value of manurial practices. And even though the results of these estate trials cannot therefore be subjected to tests of statistical significance, it is proposed to draw certain conclusions that may be of practical value and to indicate lines of approach for future work.

Columbia Estate, Icacos

Trial I

The first trial was laid down on coconuts planted in 1935 on a sandy alluvium, the chemical analysis of which follows :

Nitrogen %	*Avail. PO_4 ppm.*	*Exch. K_2O ppm.*	*Lime requirement tons/acre*
0.09	18	50	1.05

Although available nutrients were low, the area was giving high yields due in no small measure to favourable ground water movement.

The treatments involved various combinations of nitrogen, phosphorus, potash, lime and pen manure the rates of application being :

Nitrogen (N) as ammonium sulphate—4 lbs./tree/annum

Phosphorus (P) as double superphosphate—4 lbs./tree/annum

Potassium (K) as muriate of potash—4 lbs./tree/annum

Lime as one application to full lime requirement—34 lbs./tree

Pen manure as one application—150 lbs./tree

Plots of 16 (4 × 4) trees were used with 2 or 3 replications for the more important treatments and a single guard row was used round each plot. All ripe nuts were harvested in July 1946 at the beginning of the experiment and the fertilisers were applied by broadcasting round the tree. Harvesting was done by climbing the trees at 3 monthly intervals, the crop year being July-June.

The yields in nuts per tree are given in Table I and expressed as a percentage of the control in Appendix I.

TABLE I. *Average number of nuts per tree.*

	1946–47	1947–48	1948–49	1949–50*
Controls	92	55	55	52
Nitrogen (N)	90	52	58	34
Phosphate (P)	90	62	67	47
Potash (K)	92	68	62	50
Pen manure (FYM)	101	56	58	46
Lime (L)	113	78	88	82
N + FYM	100	60	62	45
P + FYM	116	78	70	54
K + FYM	99	65	51	42
N + L	87	60	95	50
P + L	102	65	93	49
K + L	89	74	71	67
PM + L	83	56	68	58
N + FYM + L	115	62	69	54
P + FYM + L	114	57	65	60
K + FYM + L	102	73	79	66

*Less last quarter when picking was impossible due to wet weather conditions.

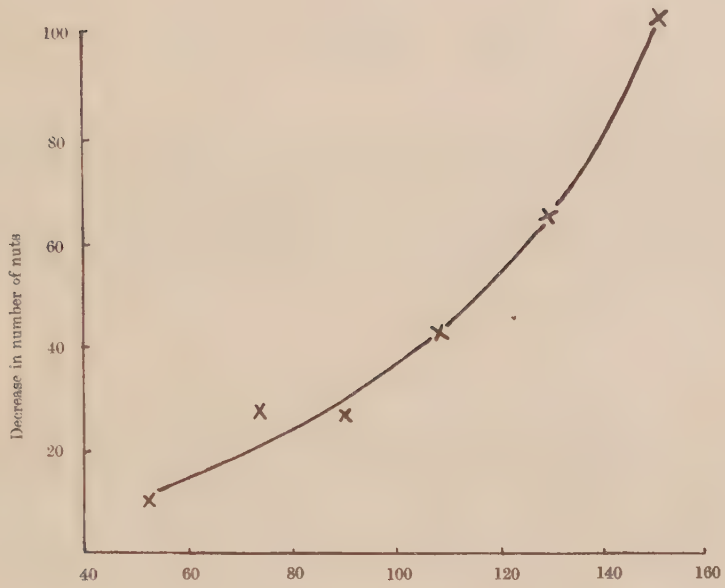
The first feature that stands out in the yield figures is the heavy fall in yields in all treatments and controls that occurred between the 1946–47 and the 1947–48 seasons. This drop was undoubtedly a result of the severe drought that occurred in early 1947 when the dry season was exceptionally rainless and prolonged. The rainfall figures over the period of the trial are given in Table II.

TABLE II. *Rainfall in inches, July to June*

	1946–47	1947–48	1948–49	1949–50
Dry season (Feb.–May)	2.5	14.0	7.2	11.5
Total ...	44.5	57.1	45.4	83.4

The effect of drought on yield has been analysed by arranging the yields in the control plots in classes differing by 20 nuts. In Table III the decrease in number of nuts is shown to vary with the original level of bearing and this decrease in yield is plotted against pre-drought yields in Fig. I.

Fig. I



Relation between decrease in number of nuts and original level of bearing

Table III

No. of nuts	No. of trees	Average nuts per tree 1946–47	1947–48	Decrease
40–60 ...	11	53	43	10
61–80 ...	14	73	45	28
81–100 ...	13	90	64	26
101–120 ...	10	108	66	42
121–140 ...	9	129	65	64
Over 140 ...	5	150	46	104

It is clear that the effect of the drought has been more marked in the high yielding trees and that the drop in yields is proportional to the 1946–47 yields. The after effect of this drought lasted for at least 2 years, yields only beginning to return to normal with the 1949–50 crop. Patel (1938) quotes Park that a drought experienced in Ceylon affected yields for a period of two years subsequently.

With such an overriding effect of drought it is to be expected that responses if any to fertilisers would be obscured. From Appendix I, where the yields are given as a percentage of the controls for each year, there is an indication that higher yields have been given by treatments containing lime alone or in combination with potash and pen manure, but no significance can be attached.

It is unfortunate that no figures are available on copra per nut, for number of nuts per tree is only one factor determining yields and it may be that some treatments while not increasing number of nuts have increased copra per nut. It was not possible however to organise the cracking of nuts from each plot to obtain this data.

The conclusion to be drawn from this trial is that drought conditions will override any manurial practice and that even when recovery from the drought is occurring no treatment can produce any effect worthy of economic consideration.

The second trial which was planned for an estate on a clay soil in the same area was never started.

Trial II

Most of the coconuts on this estate are growing on a narrow coastal strip, in some places only two hundred yards wide, bounded by a swamp on the landward side.

There was a considerable range in appearance and productivity of the trees and trials were laid down on a high and a low yielding area. Comparative soil analyses for the good and bad areas follow.

	Nitrogen %	*Avail. PO_4 ppm.*	*Exch. K_2O ppm.*	*Lime requirement tons/acre*
Good area ...	... 0.11	15	33	1.0
Bad area ...	... 0.04	19	98	0.3

In Trial II on the high yielding area the following treatments were used.

(1) Control

(2) Nitrogen (N) as ammonium sulphate—3 lbs./tree/year

(3) Phosphorus (P) as superphosphate—3 lbs./tree/year

(4) Potassium (K) as muriate of potash—3 lbs./tree/year

(5) NP as (2) and (3) above

(6) NK as (2) and (4) above

(7) PK as (3) and (4) above

(8) NPK as (2), (3) and (4) above.

Each treatment was applied to a plot of 3 rows of 10 trees each, the plots lying next to each other with no guard rows. Only single plots were used except for the controls and NPK treatments where 2 plots each were included.

In Trial III the trees were in very poor condition yielding only some 15 nuts each per year. On this area a heavier fertiliser application was made at 3 times the rate of Trial II in the first year, reduced to the lower rate in the second and third years.

The fertiliser was broadcast round the trees in February 1947, during the dry season, and the first picking made in April. Thereafter pickings were made at 4 monthly intervals giving 3 harvests a year. It would have been preferable to have made 4 or 5 harvests a year but expense and difficulty in securing pickers precluded this. The fertiliser applications were repeated in 1948 and 1949.

Only yields of full bearing trees were taken, supplies and blanks being omitted in calculating the average yield per tree. The yields are given in Table IV and are shown graphically in Fig. 2.

TABLE IV. *Average Number of Nuts per Tree*

	1947	1948	1949	1949 yields as % of '47
Controls ...	68	64	71	104
N	58	79	75	**130**
P	69	69	88	127
K	60	64	71	118
NP	52	78	91	**174**
NK	48	61	96	**200**
PK	56	60	64	114
NPK ...	68	73	96	**141**

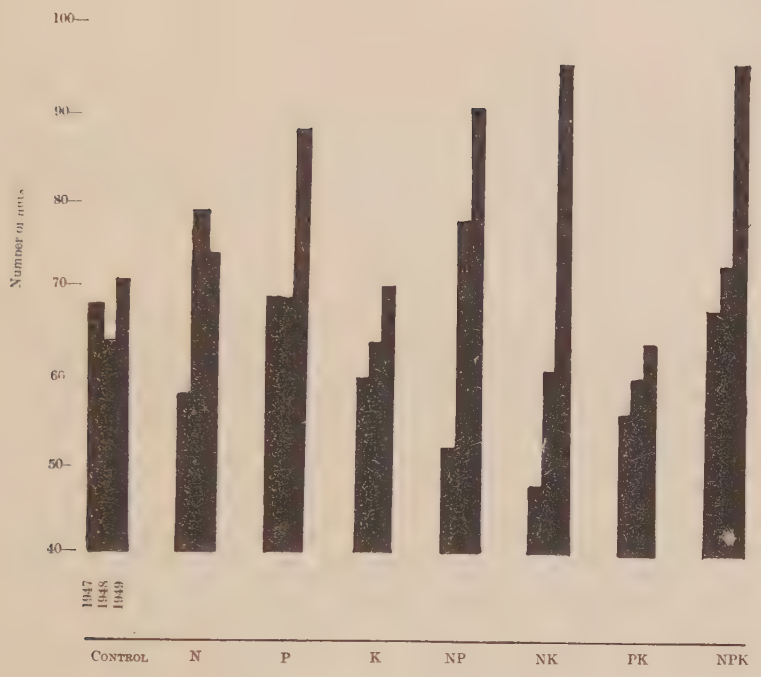
The yields in the first year can be assumed to be pre-manurial and the last column of Table IV shows the 1949 yields as a percentage of the pre-manurial 1947 yields. These figures show an increase of 30 per cent. or more only in treatments containing N. NK would appear the outstanding treatment as regards percentage increase but it is necessary to examine more carefully the actual yield figures. The NK plot started at the lowest level of bearing but reached the same peak as the average of the NPK plots.

Patel (1938) has shown that the response of coconuts to fertilisers depends upon the original level of bearing of the tree. Low yielders give a greater response than high yielders. Since there was a very considerable tree to tree variation in yield in this trial it was necessary to investigate this aspect.

The responses of trees at different original levels of bearing have therefore been calculated. In each treatment, the trees were divided into 3 groups on their 1947 yields, low yielders with 1–40 nuts, medium with 41–80 and high with 81 or more nuts.

The yield changes in each of the groups were followed through the next two years and show a similar pattern. The low yielders increased in yield more than the medium or high yielders and similarly the medium more than the high. The full data for all plots is not presented since responses have

FIG. 2



Yields in nuts per tree over 3-year period

been mainly to nitrogen and accordingly in Table V the comparison is made of controls, treatments without nitrogen and treatments with nitrogen.

TABLE V. *Increase in numbers of nuts in* 1947 *and* 1948 *over number borne in* 1946 *for different yield classes*

	1947			1948		
	Controls	Without N	With N	Controls	Without N	With N
Low yielders ...	7	17	30	24	20	48
Medium yielders ...	1	4	11	13	13	29
High yielders ...	—18	—10	—2	—3	12	16

These results agree with Patel's findings for it is quite evident that nitrogen fertilising has led to a far greater increase among the low yielders than among the medium and high yielders. The year to year changes among the controls must be a result of normal variation, increasing yield of young trees, possible biennial bearing, &c.

This differential response to fertilisers would be a complication even in a statistical layout. Since each plot contains varying numbers of trees in each yield class and it has been shown that fertiliser responses differ, a simple analysis of variance on a standard statistical layout would give only a partial answer to a fertilising programme.

In the second year of this trial it was possible to obtain data on copra outturn. The nuts from each plot were cracked separately and the weight of wet copra determined. Using a conversion of 60 per cent. the results were expressed in copra/1,000 nuts, the normal estate practice. Since four months elapsed between pickings the nuts at each harvest would show a corresponding variation in maturity, i.e., some would be over ripe, some just mature and some under ripe. The results were highly variable and will be discussed with those of Trial III.

Trial III

As stated this trial was laid down on a very low yielding block of trees using a layout similar to Trial II but with an initial dose of fertiliser 3 times as great.

The trees had very small crowns, the leaves were yellow and unhealthy looking and average production was around 16 nuts per tree per year. The area had been neglected during the war years and had only recently been receiving cultural attention.

The routine was similar to Trial II, pickings being made at 4 monthly intervals over 3 years. In Table VI and Fig. 3 the yields are given over the 3 year period of the experiment.

TABLE VI. *Average Number of Nuts per Tree*

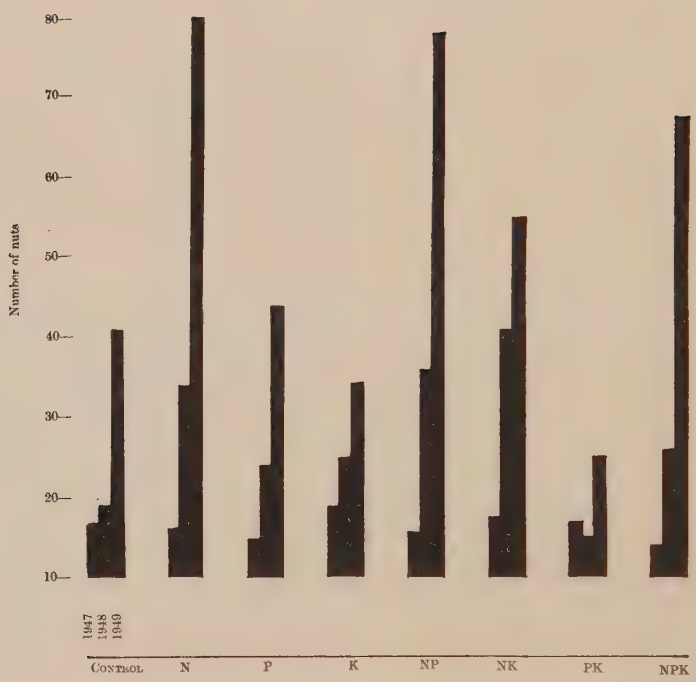
	1947	1948	1949	1949 yields as % of 1947
Control ...	17	19	41	240
N	16	34	80	500
P	15	24	44	292
K	19	25	37	179
NP	16	36	78	488
NK	17	41	55	324
PK	17	15	25	147
NPK ...	14	26	67	480

In the second year of this trial, it was possible to note by eye the great improvement in appearance of trees in treatments receiving nitrogen. The young leaves were larger and of a healthy green colour, as compared with treatments not receiving nitrogen. The response in numbers of nuts however did not really appear until the third year. An overall improvement in the block had resulted from good cultural treatment and satisfactory rainfall and this can be noted in the controls which rather more than doubled their yields over the first year. Treatments with nitrogen however gave between 300 and 500 per cent. of their original yields. Neither phosphorus nor potassium alone nor together have shown any improvement over the controls and clearly nitrogen was the dominant requirement.

The yields of the best plots have increased to levels similar to those in Trial II and serve to confirm the results of that trial, namely that the response of coconuts to fertilisers depends upon the original level of bearing of the tree. All the trees in this trial would originally have fallen in the low yielding class of Trial II, which it was shown more than doubled their yields with nitrogen fertilising.

The final level of bearing under fertilising shows considerable variation and must involve the genotype of the tree. It is only to be expected that some trees will prove more efficient physiologically in their uptake and utilisation of nutrients but this aspect of the problem can only be hinted at.

Fig. 3



Yields in nuts per tree over 3-year period

In regard to copra out turn the results again are extremely variable. In Table VII only the figures for the duplicate control and NPK plots are given for the two trials for 3 harvests.

TABLE VII. *Lbs. Copra per 1,000 Nuts*

Date		Controls	NPK
4/48	...Trial II	387	387
	Trial III	348	369
8/48	...Trial II	374	372
	Trial III	355	358
12/49	...Trial II	376	373
	...Trial III	318	325

The only consistent feature lies in the lower values for Trial III as compared with Trial II even after 3 years fertilising and with the NPK nut yields in Trial III approaching those of Trial II. Comparisons between treatments in either trial mean little in view of the high variation.

Increased copra outturn is usually associated with potash manuring but more precise experiments extended over a longer period would be needed to settle this point. It seems valid to conclude however that in these trials increased numbers of nuts have not markedly reduced copra outturn per nut.

ST. JOSEPH ESTATE, MAYARO

Trial IV

The soils on this estate range from a sandy coastal strip to a heavy clay further inland. Trial IV was laid down on the coastal sand and the analyses for the 2 experimental blocks follow. They represent composite 0–12″ samples.

	pH	*Lime Requirement tons (acre)*	*N%*	*Avail. PO_4 ppm*	*Exch. K_2O ppm*
Block A	4.8	1.0	0.08	4	72
Block B	5.0	1.0	0.08	8	34

The soil was distinctly acid and again lacking in nitrogen and minerals particularly phosphate. The higher potash figure for Block A resulted from potash fertilising in the past.

The treatments were

(1) Control

(2) Nitrogen (N) as ammonium sulphate—4 lbs./tree/annum

(3) Phosphorus (P) as superphosphate—4 lbs./tree/annum

(4) Potassium (K) as muriate of potash—4 lbs./tree/annum

(5) NPK as 4 lbs. of each of the above.

Two blocks of each of the above treatments were laid down with plots of 2 rows of 9 trees each in Block A and 2 rows of 10 trees in Block B. Each plot was separated by a guard row.

The fertilisers were first applied in March 1947 and a routine of harvesting similar to Trials II and III was adopted.

The yields over 1947–49 constitute Table VIII.

TABLE VIII. *Average Number of Nuts per Tree*

	1947	1948	1949	1949 yields as % of 1947
Control ...	81	64	65	80
N	84	74	67	80
P	81	79	71	87
K	85	69	69	80
NPK ...	84	80	84	100

The 1947 yields were high, averaging over 80 nuts per tree. In the next 2 years a fall in yields occurred in all plots except those receiving NPK. Taken in conjunction with the Cocal trials it can be concluded that where trees are yielding well, in this case, over 80 nuts per annum little or no increase can be secured from fertilising with standard N, P and K mixtures.

The figures for copra/1,000 nuts are again very variable and are not reproduced. They are lower than those for the Cocal trials though numbers of nuts are fairly similar. Again, a longer experimental period would be necessary to determine whether fertilising would improve copra outturn.

Trial V

On that section of this estate where the coconuts were growing on an acidic heavy clay the problem was rather different. The trees had grown well and given high yields but at about 20 years of age they had started to die. The symptoms were a general yellowing of the leaves, premature nut and leaf fall and fairly rapid death of the tree.

Treatments tried were an NPK mixture and lime, separately and together. No response in yields occurred and the figures are not reproduced. These yields were in the region of 80–100 nuts per tree per annum ; nor was there any apparent reduction in the numbers of trees dying in each plot.

One possible explanation lies in the water relations of the soil. The heavy clay suffers from impeded drainage and deep drains exist to carry off excess water in the rains. In the dry season on the other hand the soil dries out and cracks develop. Surface roots therefore suffer in the dry season and deep rooting is inhibited by water logging in the rains. The balance is possibly so delicate that an unusually dry season may result in so many of the surface roots being killed that the tree does not recover when the rains start. It is difficult to explain however why the trees should survive for some 20 years and give good crops under such conditions. It is a known fact that coconuts are not long lived on many of the similar inland clays of Trinidad.

Another possible explanation may lie in the toxic accumulation of some metal such as aluminium or manganese under acidic conditions. Liming should help to ameliorate such a condition. Planting of cocounts on such heavy soils is however, no longer customary in Trinidad.

Discussion

The carrying out of fertiliser trials or any other cultural trials on the coconut presents enormous difficulties. The wide spacing of the crop necessitates large experimental areas, the response of the tree to any treatment is slow and harvesting of the crop needs to be regular and continuous. Where the crop is grown over a fairly wide range of soils and rainfalls, it is clearly impossible to carry out full statistical experiments on a large number of sites and the results for one area can evidently not be applied to another. What general conclusions may however be drawn from this series of trials ?

In the first trial it is clear that a very severe dry season overrides any manurial practice. Liming may have had a slightly beneficial effect but whether on soil structure or by facilitating uptake of other elements would need further investigation. de Verteuil (1934) working on an inland acidic silty loam had found beneficial effects on yield from an application of 10 tons of lime to the acre and a somewhat smaller effect from a full NPK dressing. The initial level of bearing, however, averaged 25 nuts per tree per year, a low figure.

From the two Cocal trials, the importance of the initial level bearing on the response to manuring stands out. Trees averaging 70–80 nuts a year show little response to nitrogen fertilising but where they had been giving only 15–20 nuts per annum a 3 to 5 fold increase in yield resulted.

In a mixed field of high and low yielders, a fertilising policy should therefore involve selective manuring, fertilisers being given perhaps in the first instance only to the obviously low yielders.

Salgado (1946) in a carefully controlled factorial experiment in Ceylon found over a period of 8 years a response to nitrogen as the equivalent of 2½ lbs. sulphate of ammonia applied biennially but he found that 5 lbs. depressed yield though not significantly. He states that the coconut is almost the only case of a tropical crop in Ceylon to show such a minor and indefinite response to nitrogen. Under Cocal conditions the response to nitrogen particularly of the low yielders is most striking.

In contrast to the results with N, the absence of any response to potassium is surprising. Salgado found an almost linear response to potassium fertilising but it did not occur until the 3rd year with the equivalent of 3 lbs. muriate of potash. Increased copra per acre was partly due to a better copra outturn per nut and nitrogen showed an adverse effect. The results only became significant after the 4th year so that these trials under discussion could not be expected to give any information on this point.

At St. Joseph Estate, the use of fertilisers on the beach sand would not be economic and the problem of coconuts on a heavy clay requires further investigation.

Clearly a simpler technique for assessing the nutritional requirements of the coconut is badly needed. Foliar analysis provides a valuable techinque for many crops and Chapman and Gray (1949) have made such a study in another palm, the oil palm. Sampling would prove a difficulty but could be done by a picker on one occasion as compared with the frequent climbing necessary for harvesting a field trial.

A second possibility lies in the use of nut water, where Salgado (1951) has made a note-worthy advance in regard to potash manuring. He found a close correlation between the potash content of the water and the yield of copra per acre. The method is simple and preliminary analyses of nut water in Trinidad by the rapid colorimetric method for potash have shown a wide range in potash content of nuts from different areas. Similar rapid colorimetric methods have also shown differences in phosphate, magnesium, calcium and manganese levels. It has not been possible however, to make any quantitative comparisons with yield nor to extend this line of work.

Acknowledgments

The authors acknowledge the work of Dr. E. Phillis, formerly Chief Scientific Officer in the Department of Agriculture who was responsible for laying down the first of the trials.

Also, the whole-hearted co-operation of Messrs. R. W. Wharton, G. Bovell and J. de Meillac, Managers of the three estates where these trials were laid down is gratefully acknowledged. They devoted a considerable amount of

their time to supervising the experiments and recording the yields, a task of some difficulty where only untrained labour was available for the various operations.

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APPENDIX I

Trial I. Mean Yields as Percentage of Controls

	1946–47	1947–48	1948–49	1949–50*
Controls	100	100	100	100
Nitrogen (N)	98	95	105	65
Phosphorus (P)	98	113	122	90
Potash (K)	100	124	113	96
Pen manure (FYM)	110	102	105	88
Lime (L)	123	142	160	158
N + FYM	109	109	113	87
P + FYM	126	142	127	104
K + FYM	108	118	93	81
N + L	95	109	173	96
P + L	111	118	169	94
K + L	97	135	129	129
FYM + L	90	102	124	112
N + FYM + L	125	113	125	104
P + FYM + L	124	104	118	115
K + FYM + L	111	133	144	127

* Less last quarter.

OBITUARIES

G. E. L. SPENCER, D.I.C.T.A.

We have to record with deepest sorrow the death on 10th July, 1952 of Mr. George Edmund Laurie Spencer, who was Manager of the B.W.I. Cacao Research Scheme Field Experiment Station at River Estate, Trinidad.

Mr. Spencer was educated at the Lodge School, Barbados, and was a student at the College from 1925–1928. He was awarded the D.I.C.T.A. and was the first recipient of the Stephens Gold Medal awarded to the best final year Diploma student. Mr. Spencer was appointed to the College Staff in 1928, as Field Assistant to Professor Cheesman for Banana Research. He was seconded to the Government of Mexico for a year from June 1942, to study cacao and related species. In 1943, he was promoted to Junior Lecturer and in 1948 was appointed Manager of River Estate. His long and meritorious service with the College was recognised on the occasion of the Silver Jubilee in 1951 by the presentation of a Long Service Medal.

Those who knew River Estate after the long period of neglect occasioned by the war appreciate the hard work and zeal with which Mr. Spencer transformed the derelict fields into the 'model' cacao estate and first class experiment station that it is today.

Mr. Spencer was of a generous and kindly disposition, and he soon won the confidence of those who worked or otherwise came into contact with him. He had been ill for a short time before leaving on medical advice to spend a vacation in his native Barbados, but two months after his arrival he suffered a severe stroke from which he did not recover.

To Mrs. Spencer and their daughter Carol Anne, and to his bereaved relatives, we extend our deepest sympathies.

HARIHAR PERSAUD

Harihar Persaud was spending the summer vacation in British Guiana, when on 24th July, 1952, he was killed when a car in which he was travelling overturned.

Harihar Persaud was born at De Kinderen, British Guiana in 1930, and attended Corentyne High School where he obtained the Senior Cambridge School Certificate. He came to the Imperial College of Tropical Agriculture in September, 1951 as a British Guiana Government-nominated scholar, and had completed the first year of the course for the D.I.C.T.A.

We extend our sincere condolences to his relatives.